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DRAFT Integrated Aquatic Community and Water Quality Monitoring of Wadeable Streams in the Klamath Network

Natural Resource Report NPS/KLMN/NRR—2011/xxx

ON THE COVER
West Branch Mill Creek, Redwood State and National Parks, September 2009
Photograph by: Mara Denny

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June 2010

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

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Please cite this publication as:

Dinger, E. C., D. A. Sarr, S. R. Mohren, C. E. Stanley, and K.M. Irvine. 2011. Integrated aquatic community and water quality monitoring of wadeable streams in the Klamath Network. Natural Resource Report NPS/KLMN/NRR—2011/XXX. National Park Service, Fort Collins, Colorado.

NPS XXX, June 2010

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Acknowledgments

Many individuals have contributed to the design and development of this protocol. Bob Hoffman (USGS) was instrumental in getting the ball rolling in the early stages of the Klamath Network aquatic monitoring projects, and did much of the background work. Park specialists have contributed at many stages and include: Nancy Nordensten, Mike Magnuson, Sean Eagan, John Roth, David Hering, Mark Buktenica, David Anderson, Vicki Ozaki, Brian Rasmussen, and Jennifer Gibson. Guidance on quality control, to improve the overall project, came from Roy Irwin (Water Resources Division). Within the Klamath Network, Dennis Odion and Sean Smith helped as experts in riparian vegetation. The pilot project field crew maintained a great spirit, despite the shifting nature of the pilot study: Travis Albert and Mara Denny. Elizabeth Perry deserves special mention for logistical support and her editing skills.

1.0 Background and Objectives

1.1 Rationale for Integrated Monitoring of Streams

The National Park Service (NPS) recognizes that "aquatic resources are some of the most critical and biologically productive resources in the national park system" and that they "are vulnerable to degradation from activities both within and external to parks" (NPS 2000). Wadeable streams of the Klamath region are sensitive ecosystems and distribute water, sediments, and nutrients across landscapes. Consequently, streams integrate upstream processes of landscape scale impacts, such as land use and consumptive uses (e.g., water diversion or extraction) (Hynes 1975, Wang et al. 1997, Allan 2004, Allan and Castillo 2007). Stream communities serve as powerful monitoring tools to the watershed on multiple temporal scales including short-term impacts such as acute point-source stressors (e.g., sewage spills) and chronic long-term impacts such as non-point source stressors (e.g., sedimentation, climate change, livestock grazing, mining) (Rosenberg and Resh 1993, Karr and Chu 1999). Stream flow reflects mountain snowpack, spring-seeps, water table status, and direct precipitation (Leopold 1997), providing a linkage to atmospheric dynamics and synoptic stressors (e.g., climate change) (Meyer et al 1999, Barnett et al. 2005). Within streams themselves, water flow acts as a "master variable," controlling geomorphic, nutrient transport, disturbance, and biological dispersal processes (Gray and Fisher 1981, Newbold 1992, Leopold 1997, Hart and Finelli 1999).

The Klamath Network vital sign selection process resulted in indentifying two aquatic resource vital signs: Aquatic Communities and Water Quality (Sarr et al. 2007). Prioritization of these vital signs was driven by their ecological and management significance, legal requirements for management reporting, and their feasibility for monitoring. Generally, it was agreed by Klamath Network parks that monitoring should be integrative in nature and encompass physical, chemical, and biological characteristics of aquatic ecosystems. Current existing identified stressors of park aquatic resources included (1) climate change; (2) atmospheric deposition of pollutants and nutrients; (3) introduced and invasive species; (4) recreational visitor use; and (5) land use, including park maintenance activities. However, our multidisciplinary monitoring plan is not focused on specific stressors, either currently known or anticipated. Rather, we aim to develop a broad scheme focused on the overall ecosystem, so that any significant stressor effect may be detected. Although stream physical, chemical, and biological components compose different scientific disciplines, we chose to develop an integrated monitoring protocol to reflect the view of streams as integrative ecosystems within park landscapes.

Aquatic communities and water quality are intrinsically related. The "quality" of a water body is usually related to its ability to support life. In the words of Dr. Robert Wetzel, late Professor of Aquatic Ecology, University of North Carolina, Chapel Hill, "Water quality is biological" (Wetzel 2001). Hence, water quality goes beyond regulatory standards, and in this protocol we strive to use "water quality" in terms of the "natural conditions," and not just human consumptive needs. This is aligned with the broad purpose of the National Park Service in maintaining natural conditions "unimpaired for future generations."

Initial selection of aquatic communities and water quality did not discern between lentic (lake and pond) versus lotic (stream) habitats. Fundamental differences in ecosystem structure and process of streams versus lakes dictated a basic division in sampling methodology. Lentic sampling is covered in a separate protocol (Dinger et al. in review).

Streams are dynamic ecosystems that vary in time and space. The River Continuum Concept (Vannote et al. 1980) offers a conceptual framework for understanding linkages and importance of upstream processes (e.g., headwater streams) to downstream processes (e.g., lowland streams) (Figure 1). In brief, the River Continuum Concept lays out the idea that physical and biological conditions vary in predictable, interconnected, and cumulative ways from headwaters to ocean. For instance, in heavily forested headwater reaches, where stream channels are narrow, steep, and shaded, terrestrial (allochthonous) inputs such as falling leaves are processed (e.g., consumed by macroinvertebrates termed "shredders"), so that smaller particles are then consumed by biota downstream (macroinvertebrates termed "filterers"). As stream order increases, and riparian canopies cannot cover the wider channels, light impinging upon the stream bottom increases, and algal growth on stream substrates (termed "periphyton," autochthonous inputs) becomes the primary food source for organisms. With rivers deepening and widening further downstream, a secondary resource shift from periphyton to phytoplankton occurs, and rivers start to resemble lentic ecosystems. Fish assemblages shift, from fast water fish with high oxygen demands to slower water fish, and their feeding guilds change to reflect the changing food base and physical conditions. Because many watershed processes aggregate down the watershed, stream communities are not only indicative of local conditions but also are often a direct reflection of upstream biological and geological processes, including environmental impacts (e.g., Ward and Stanford 1983).

Water quality monitoring and stream bioassessments have a long history, and relationships to stressors go back to the 1850s (for example, the London sewage pollution of the River Thames, causing the "Year of the Great Stink" in 1858). Established effects of acid mine pollution (Gerhardt et al. 2004), thermal stress (Vinson 2001), denuding of riparian zones (Waters 1995), livestock grazing (Armour et al. 1994), sewage impacts (Whitehurst and Lindsey 1990), exotic invasive species (Hall et al. 2006), and sediment pollution (Waters 1995) have all been extensively studied, establishing stressor-response relationships, providing a rich context for monitoring and bioassessment. Consequently, aquatic habitats are known to respond to physical and biological stressors in predictable ways (e.g., Resh and Rosenberg 1984, Rosenberg and Resh 1993). As temperature-sensitive organisms with known stress responses, aquatic communities provide important indication and aid in interpretation of environmental alterations such as climate change.

Since streams are integrated ecosystems central to park landscapes, we have chosen to monitor physical, biological, and chemical parameters in concert. These varied parameters provide a broad view of change in time and space. For instance, macroinvertebrate assemblages respond rapidly to impacts, while fish and amphibians (with longer life cycles) will demonstrate longer duration, time-integrated responses. Changes in geomorphic and riparian vegetation features manifest at yet longer time scales. The use of multiple indicators for measuring ecosystem change will provide us with an integrated and robust system for interpreting natural dynamics, and detecting trends in key ecological features and diverse impacts over time.

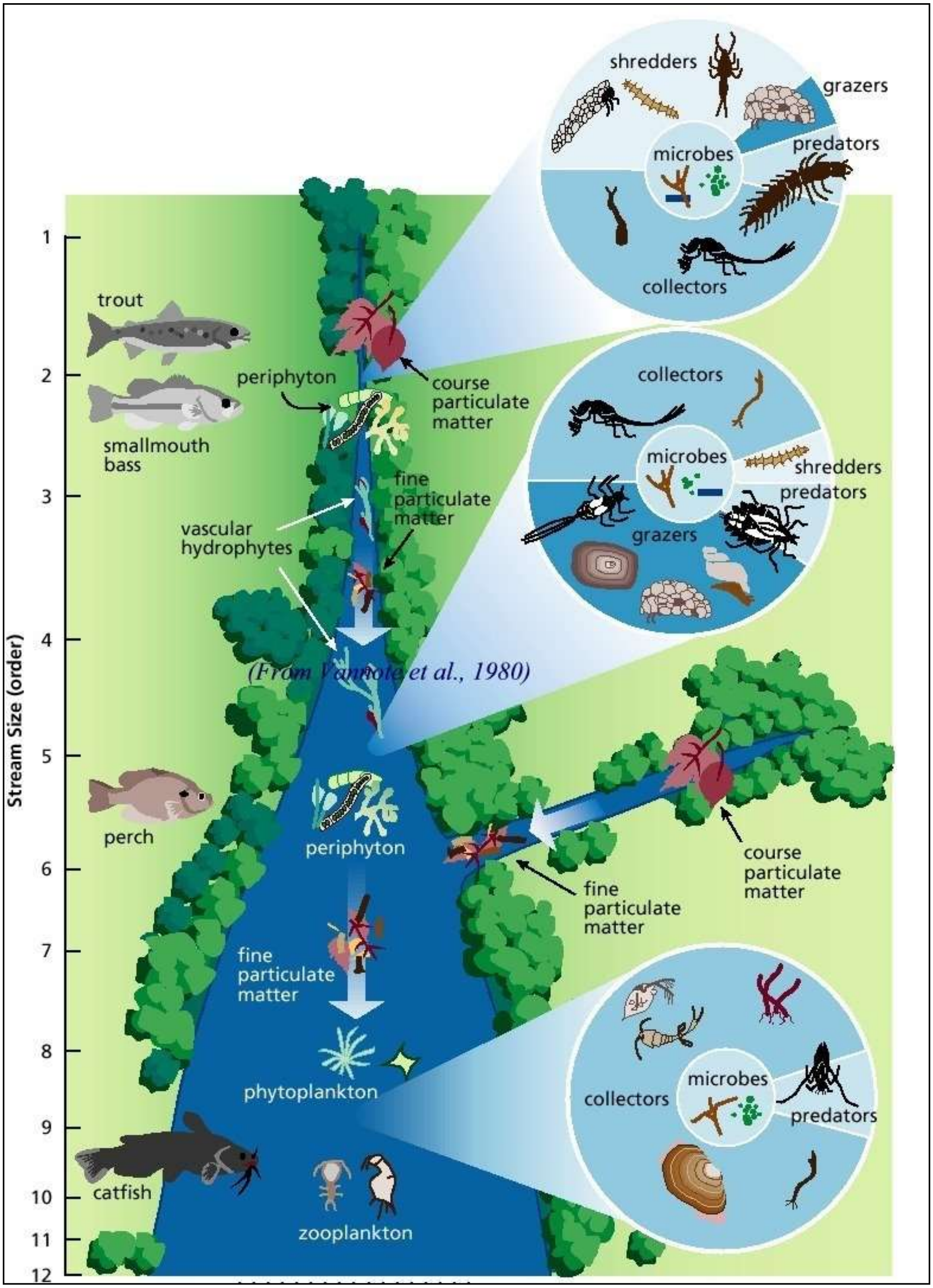

Figure 1. Conceptual model of stream ecosystems known as the River Continuum Concept, showing changes in aquatic community along a downstream gradient (from Vannote et al. 1980).

1.2 Link to National and Regional Strategies

Current stream monitoring is carried out by many agencies, all with differing protocols and objectives:

- County Health Departments
- State agencies:
    - Departments of Environmental Quality
    - Departments of Game and Fish
    - Departments of Forestry
- Federal agencies:
    - USDI Bureau of Land Management
    - USDI United States Geological Survey
    - USDA Forest Service
    - USDI Environmental Protection Agency
    - USDI National Park Service
    - USDI Bureau of Reclamation

The monitoring objectives of each agency dictate different approaches to sampling design and protocols. For example, the objectives of the US Forest Service (USFS) Upper Columbia Basin effectiveness monitoring program (PACFISH/INFISH Biological Opinion, PIBO) focuses on salmonid habitat assessment and surveys over 250 Upper Columbia Basin sites every year. The Environmental Protection Agency (EPA), through the EMAP (Environmental Monitoring and Assessment Program) project aimed to develop monitoring tools for a range of end-users over the entire western US and to conduct Wadeable Streams Assessments every 5 years in the National Rivers and Stream Assessment (NRSA). Bureau of Land Management (BLM) aquatic monitoring programs are more project-specific (e.g., monitoring aquatic macroinvertebrates in specific drainages containing acid mine effects) and to date are not under any national BLM plan. They are also dependent upon district or regional offices to determine specific protocols, with monitoring often done in conjunction with partners (for example, the PIBO project by the USFS includes BLM lands). However, the BLM is currently taking steps to develop a national probabilistic monitoring design in conjunction with the Utah State University National Aquatic Monitoring Center. The United States Geological Survey (USGS) has developed protocols under the National Water-Quality Assessment (NAWQA) program, which focuses on targeted-site designs to study the causes of water quality problems. Bureau of Reclamation monitoring protocols are also project-specific, and vary accordingly.

State agency monitoring is focused on ensuring that waterways meet water quality standards for listed beneficial uses (including fish and wildlife) established by state and federal law (e.g., Endangered Species Act, Clean Water Act). In California, stream monitoring is overseen by the Surface Water Ambient Monitoring Program (SWAMP) of the State Water Resources Control Board. The SWAMP program established stream monitoring protocols (Ode 2007) that are used by individual state agencies conducting stream monitoring (Regional Water Quality Control Boards, California Department of Fish and Game, municipalities, counties, etc.). The SWAMP protocols are close modifications of the EPA EMAP program. In Oregon, the task of stream monitoring is split between two state agencies: Department of Fish and Wildlife (ODFW), and Department of Environmental Quality (ODEQ). The ODFW conducts habitat and fish surveys, whereas the ODEQ conducts macroinvertebrate and water quality analyses. The ODFW habitat and fish protocols are derived from protocols developed at Oregon State University, in conjunction with USFS researchers. The ODEQ protocols focus on macroinvertebrate collection (EMAP based), water chemistry, and continuous monitoring.

Lastly, the National Park Service is implementing nationwide water quality monitoring through the Inventory and Monitoring Program. However, the vital sign selection process, unique to each network, along with varied resource concerns specific to networks have resulted in different approaches to water quality monitoring. For example, the Cumberland Piedmont Network is monitoring selected water quality parameters (pH, acid neutralizing capacity, nutrients), all through water samples on a monthly or bimonthly basis. The Cumberland Piedmont protocol does not sample the biological communities or physical habitat parameters. However, each network performing water monitoring is required to sample a set of "core" parameters (pH, temperature, conductivity, dissolved oxygen), but the methodology and frequency vary from network to network. A brief overview of the Inventory and Monitoring networks in the western US, and their protocol status, is given in Table 1.

In the Klamath Network, we selected parameters to meet the needs of our parks. Methodology was selected from three existing protocols: (1) EMAP, (2) ODEQ, and (3) SWAMP. The specific methods were those that best matched our needs. Deviations from these protocols are based on logistic or budgetary necessities and are detailed below. In most cases, measured parameters will allow comparisons, and deviations are omitted parameters, rather than different measurement techniques.

Table 1. Summary of western US NPS Inventory and Monitoring Network stream monitoring protocols. All parameters listed are for streams; many are still in development. Networks may be monitoring other indicators in other habitats (spring-seeps, lakes, etc.). DEQ = Department of Environmental Quality; NAWQA = National Water-Quality Assessment; EMAP = Ecological Monitoring and Assessment Program; SWAMP = Surface Water Ambient Monitoring Program. PIBO = PACFISH/INFISH Biological Opinion. Note that Wyoming and Montana DEQ protocols are based on EMAP.

Network	Parameters	Protocol Sources
Greater Yellowstone	Chemistry, macroinvertebrates	Wyoming and Montana DEQ, NAWQA
Mediterranean Coast	Amphibians, fish	USGS Amphibian protocols (Corn et al. 2005)
Mojave Desert	Water quality, stream discharge	Unknown - still in draft stage
North Coast and Cascades	Fish	Unknown - still in draft stage
Northern Colorado Plateau	Chemistry	Utah DEQ, USGS
Rocky Mountains	Macroinvertebrates, periphyton, chemistry, habitat	EMAP
San Francisco Bay Area	Stream flow, water quality, fish	EMAP, SWAMP
Sierra Nevada	Chemistry	
Sonoran Desert	Fish, macroinvertebrates, periphyton, water quality, physical	EMAP

Table 2. Summary of western US NPS Inventory and Monitoring Network stream monitoring protocols. All parameters listed are for streams; many are still in development. Networks may be monitoring other indicators in other habitats (spring-seeps, lakes, etc.). DEQ = Department of Environmental Quality; NAWQA = National Water-Quality Assessment; EMAP = Ecological Monitoring and Assessment Program; SWAMP = Surface Water Ambient Monitoring Program. PIBO = PACFISH/INFISH Biological Opinion. Note that Wyoming and Montana DEQ protocols are based on EMAP (continued).

Network	Parameters	Protocol Sources
Southern Colorado Plateau	Chemistry, macroinvertebrates	NAQWA
Upper Columbia Basin	Continuous (pH, DO, temperature, etc.), macroinvertebrates, habitat	EMAP, PIBO

1.3 Monitoring History

Past monitoring and research in Klamath Network park units was summarized in the Network's Phase II Water Quality Report (Hoffman et al. 2005). The comprehensive summary therein should serve as the primary source for integrating future monitoring into historical context. However, special attention to specific, ongoing research and monitoring programs within each park served to inform this protocol. Most of these projects are stressor/response driven (e.g., specific sedimentation monitoring due to abandoned logging roads in RNSP) or inventory projects. In integrating these projects in the current monitoring protocol, we found that the best is to use our protocol to supplement ongoing monitoring, e.g., adding macroinvertebrate and riparian monitoring to the ongoing sediment monitoring.

1.3.1 Crater Lake National Park (CRLA)

The bulk of monitoring and research projects in CRLA have occurred within the caldera and in Crater Lake proper. Extra-caldera monitoring and research has focused on exotic brook trout (*Salvelinus fontinalis*) eradication and restoration of bull trout (*S. confluentus*) in Sun Creek. Other studies have included amphibian and fisheries surveys (e.g., Bergmann 1997 [Amphibians], Wallis 1947 [trout]) or flow and water chemistry (Frank and Harris 1969).

1.3.2 Lassen Volcanic National Park (LAVO)

Aquatic monitoring and research in LAVO have focused on either lake inventories, with associated fish and amphibians (e.g., Stead et al. 2005, Parker 2008), or on geothermal hot springs (e.g., Thompson 1983, Siering et al. 2006). Existing water quality data are summarized in a NPS Water Resource Division Baseline Water Quality Data Inventory and Analysis report (NPS-WRD 1999). Very little has been done in the streams of LAVO.

1.3.3 Oregon Caves National Monument (ORCA)

The NPS WRD Baseline Water Quality Data Inventory and Analysis report (NPS-WRD 1998) for ORCA lists 19 water quality stations within the park: 11 in the cave and 8 outside the cave. These stations are limited to water chemistry (including temperature, dissolved oxygen, etc.). There have been no biological surveys or physical habitat surveys of Cave Creek or Panther Creek (the two named creeks in the park), although the cave habitats and fauna have been surveyed (Roth 1994).

1.3.4 Redwood National and State Parks (REDW)

The streams and creeks of REDW have a rich and diverse history of monitoring and research projects. Activities within REDW have been driven by two factors: (1) Clean Water Act impaired streams [303(d) streams] and (2) threatened and endangered species. Redwood Creek, in the southern portion of the park, has been the subject of extensive sediment, temperature, and geomorphic monitoring, which remains a high priority (Hoffman et al. 2005). Within Redwood Creek, fisheries studies have included: invertebrate drift/juvenile salmonid habitat (Anderson 1981), migration (McKeon 1985), fish food habits, coho salmon (*Oncorhynchus kisutch*) monitoring (Anderson 1994), spawning surveys (1991 to 2003, e.g., Pacific Coast Fish, Wildlife, and Wetlands Restoration Association 2002), and steelhead (*O. mykiss*) monitoring (1991 – 2002, e.g., McCanne 2002).

Other monitoring in REDW has included multiple studies of fish distribution, organic debris (woody debris), and fish redd (fish egg deposition locations) composition studies. Timber industry has also done monitoring of select parameters in portions of REDW watershed (e.g., Stone 1994). An additional 18 assorted Masters theses from Humboldt State University have been completed in and around REDW (Hoffman et al. 2005). Historic and active restoration of abandoned logging roads and associated erosion control efforts has also accumulated a large body of monitoring data (Hoffman et al. 2005).

Since the historic and ongoing monitoring have been stressor driven (e.g., temperature and sediment), species-specific (e.g., coho salmon), and/or site-specific (e.g., Redwood Creek), the current monitoring protocol has been designed to *supplement, and not supplant* the ongoing monitoring.

1.3.5 Whiskeytown National Recreation Area (WHIS)

Monitoring at WHIS has historically been short-termed projects, with the exception of long-term monitoring in the reservoir, or on Clear and Willow Creeks (NPS-WRD 2000). The monitoring on Clear and Willow Creeks has been sporadic, and one site on Clear Creek has a 20 year record, but with only seven observations within that time frame. Most of this monitoring has been standard water quality variables (i.e., pH, temperature, conductance) or occasional heavy metal monitoring (e.g., copper, zinc, cadmium).

Other short-term programs have occurred since 1995, primarily in the form of USGS projects. One focused on mercury in aquatic biota (Primary Investigator: R. L. Hothem), while the other focused on overall aquatic biota, habitat, and water quality in all the watersheds of WHIS (Primary Investigator: J. T. May) (Hoffman et al. 2005). Neither of these has produced USGS technical reports or other reports. Amphibians and turtles in WHIS have been actively surveyed by USGS researchers (Bury et al. 2002).

1.4 Integrated Conceptual Model of Aquatic Communities and Water Quality

The Klamath Network presented graphical conceptual models supporting its overall monitoring design in their vital signs monitoring plan (Sarr et al. 2007). The models outlined a conceptual approach for combining water quality and aquatic communities into a unified protocol (Figure 2) that encompasses ecosystem composition, structure, and function (Figure 3). For example, we will monitor the ecosystem structure of streams (e.g., riparian cover, instream substrate, discharge) and aquatic community composition (fish, macroinvertebrates, amphibians, algal biomass). These parameters, combined with multiple water chemistry parameters (e.g., pH, alkalinity, and nutrients), will give us the opportunity to describe and evaluate functional aspects of the trophic structure of these ecosystems.

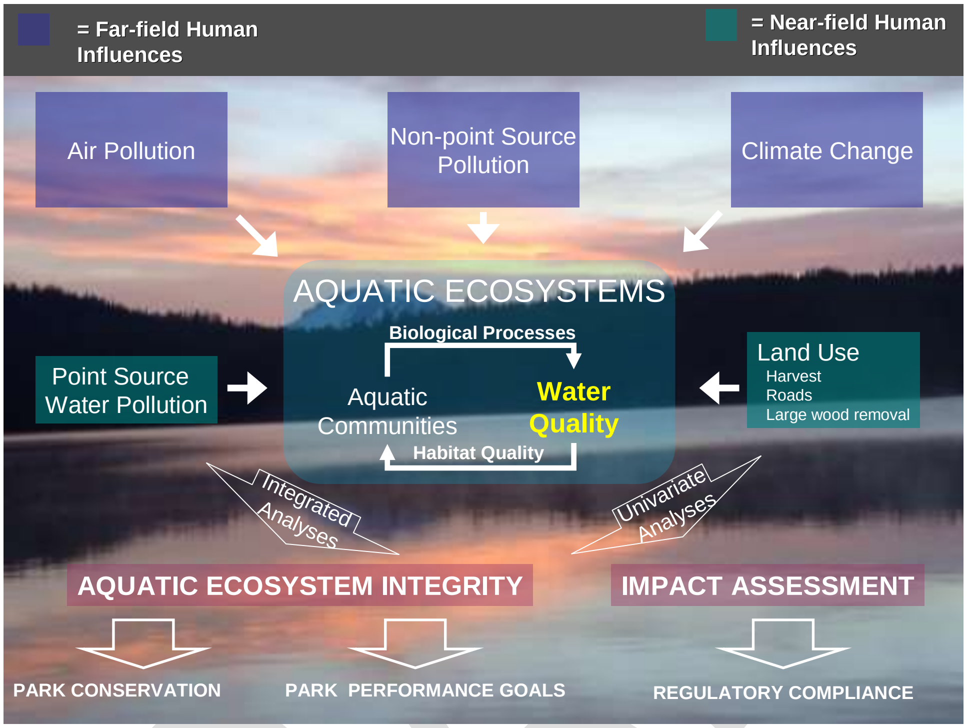

Figure 2. Conceptual ecological model showing the integral relationships between water quality and aquatic communities in aquatic ecosystems.

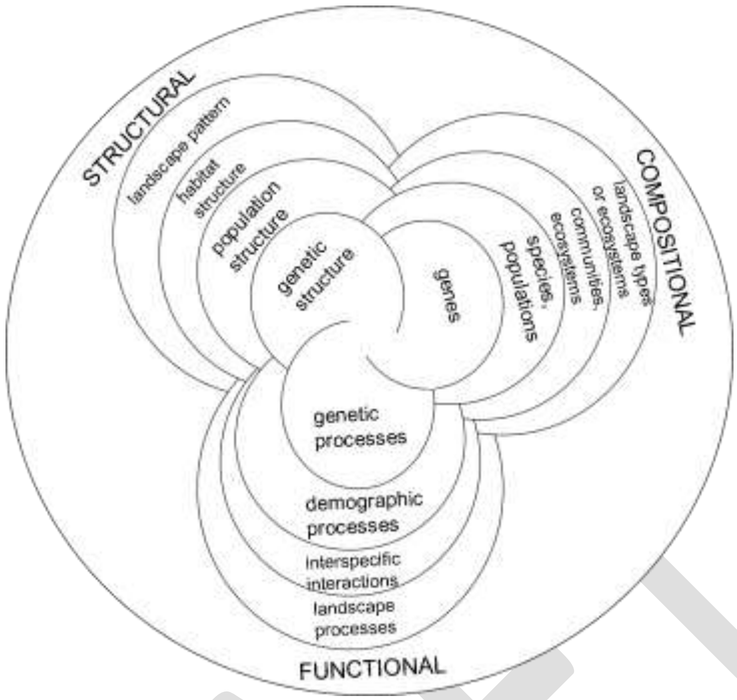

Figure 3. Conceptual model of the multiscale hierarchy of biodiversity indicators that describe composition, structure, and function at each level of organization (from Noss 1990).

In addition to integrating biological, chemical, and physical dimensions of the stream ecosystem, we employ a multispecies approach to analysis of change. Previous authors have argued that multispecies assessment provides the most comprehensive and robust way to ensure important trend detection (e.g., Karr and Chu 1999, Manley et al. 2004). Since biological assemblages contain a rich set of information, monitoring multiple species and attributes together can track changes in ecosystem composition, function, and structure better than single species or univariate (e.g., water chemistry) approaches (Clarke and Warwick 2001).

1.5 Existing and Potential Ecosystem Stressors

In addition to the Klamath Network Vital Signs scoping process, supplemental workshop for water quality monitoring (described in Hoffman and Sarr 2007) identified existing and potential stressors to the aquatic resources of the Klamath Network parks (Sarr et al. 2007, Figure 4). The identified stressors, by park, depended largely on the position of the parks in their watershed. High elevation parks, Crater Lake National Park and Lassen Volcanic National Park, identified: (1) aquatic nuisance species, (2) visitor and park activities impacts, (3) climate change, and (4) atmospheric deposition of nutrients and pollutants. Lower elevation parks, Redwood National and State Parks, Whiskeytown National Recreation Area, and Oregon Caves National Monument face a much more extensive list of potential stressors. Identified stressors of low elevation parks were: (1) temperature impairment, (2) abandoned mining operations, (3) septic field leaching, (4) herbicide applications, (5) marijuana farming, (6) cattle grazing, (7) abandoned logging roads, (8) fire management techniques, (9) upstream land use activities, and (10) recreational fishing. All stressors (recreational fishing was considered to be a part of visitor and park activities) were considered in the selection of parameters to monitor, and are briefly summarized below.

Furthermore, the aforementioned multi-parameter and multispecies monitoring schemes should be robust for emerging or unforeseen stressors.

1.5.1 Abandoned Logging Roads

A history of logging in the watersheds of RNSP and WHIS resulted in a large network of logging roads that can negatively impact streams and their biota. Roads impact streams through several mechanisms: (1) acting as a sediment source; (2) hydrological alteration (road incuts interrupt subsurface flow, so that overland flow emerges, increasing soil erosion and transport into stream channels); and (3) stream crossings, roads pass either directly through the stream, or over it with culverts. Increased sediments from roads can fill spawning gravels, thereby degrading habitat and smothering and suffocating fish eggs and aquatic invertebrates (Waters 1995). Improperly designed culverts also impede fish migration and passage (Gibson et al. 2005) and can plug with debris, dramatically increasing the risk of debris flows (Wemple et al. 2001).

1.5.2 Abandoned Mining Operations

Historic and current mining operations in the watersheds above Whiskeytown National Recreation Area stress the streams and reservoir through three mechanisms: (1) mercury and mercury methylation, (2) acidification of stream water, and (3) arsenic poisoning. Mercury is released during the amalgamation process of gold mining and by exposing more mercury in slag to the environment (Rytuba 2000). Acidification occurs when sulfite rich rocks are exposed to the atmosphere, creating sulfuric acid (Skousen et al. 2000). Acidification of streams also increases the mercury methylation process (which is the most toxic form). Arsenic comes from the finely ground tailings of gold mining and is released as downstream sediment dispersal (Straskraba and Moran 1990).

1.5.3 Atmospheric Deposition

Atmospheric contaminants have been recognized as a potential stressor of aquatic and terrestrial ecosystems for several decades (Schindler 1987, Landers et al. 2008). A classic example is acid rain, where SO_x and NO_x precursors from industrial combustion are transported thousands of kilometers from their source and deposited by precipitation, causing acidification of poorly buffered ecosystems (Likens et al. 1979). Similar concerns with nutrients (e.g., from agricultural fertilizers) and pollutants (e.g., volatile organic chemicals, toxicants, etc.) can also perturb ecosystems by eutrophication processes or toxicity effects (Landers et al. 2008).

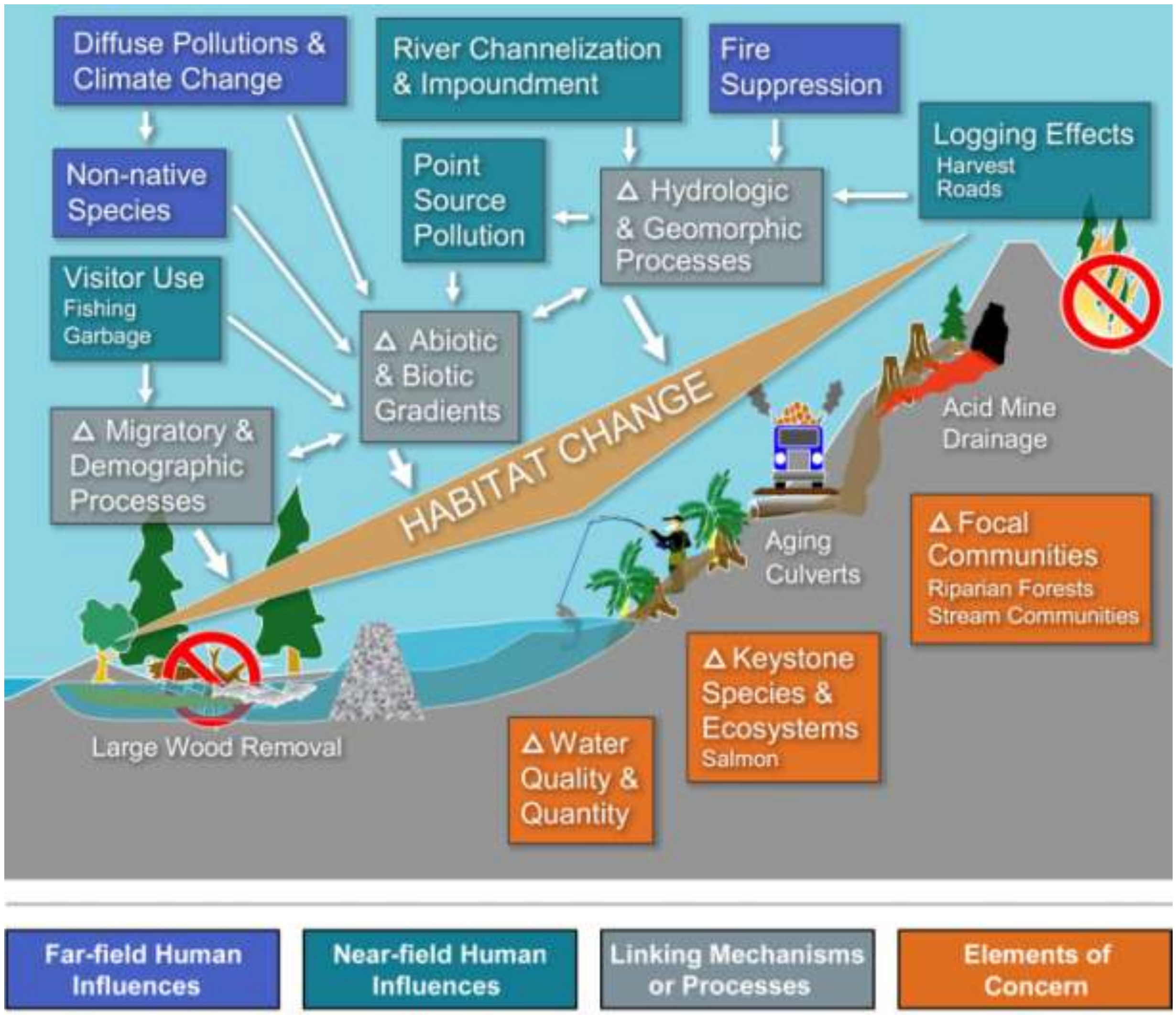

Figure 4. Conceptual model showing linkages of stressors to habitat changes and impacts to water quality and aquatic communities vital signs.

1.5.4 Cattle Grazing

Cattle grazing may impact parks of the Klamath Network in two ways: (1) trespass cattle grazing and (2) watershed impacts affecting downstream water quality. Trespass grazing is likely to be a rare event, and not prolonged; however, potential impacts include riparian zone denuding, trampling of stream biota, and increased sediments (Platts 1982). Generalized watershed impacts from grazing allotments in watersheds above park boundaries include eutrophication, fecal contamination (Roth, J. E., personal communication), and sedimentation (Belsky et al. 1999).

1.5.5 Climate Change

Concerns about global climate change impacts are well documented (IPCC 2007). Researchers have documented various physical, chemical, and biological characteristics of aquatic ecosystems can act as indicators of impacts due to climate change (McKnight et al. 1996, Arnott et al. 2003, O'Reilly et al. 2003). Even modest temperature increases in the western United States may cause significant changes to the hydrologic cycle, as manifested in earlier snowmelt, earlier ice-out on lakes, reduced summer base flows (Dettinger et al. 2004), a lower snowpack volume at lower to mid elevations (Knowles and Cayan 2001), and increased flooding due to rain-on-snow events in winter (Heard et al. 2009). Although the overall precipitation patterns are currently not expected to change as much in the Klamath Network as in other regions of the West, the hydrograph (i.e., the magnitude and timing of spring run-off) will likely shift to earlier floods. These changes will, in turn, likely affect the seasonal dynamics of stream and riparian biota (Palmer et al. 2009).

1.5.6 Fire and Fire Management Techniques

Wildland fire and fire management activities directly and indirectly affect Klamath Network streams through several mechanisms. Fuels reduction efforts change the vegetation structure, volume, and water use of vegetation. These changes, in turn, can affect the geomorphic and water temperature dynamics and nature of litter inputs to streams. Direct suppression efforts may sometimes affect streams if fire retardants enter into the water column. Wildfires typically cause temporary increases in flood and debris flow risks, which can strongly affect stream communities. Western US stream ecosystems, however, have experienced fire for millennia and fire may be an important component for maintaining riparian diversity (Reiman et al. 2005). Altered fire regimes, caused by continued fire suppression over the past decades and the buildup of fuels, combined with a drier climate, may result in more intense burns in riparian zones. More severe fires will increase the likelihood of large scale floods and erosion, negatively impacting stream ecosystems. Fires have direct, indirect, short-term and long-term impacts, including mortality of fish and invertebrates, changes in erosion patterns, woody debris accumulation, and vegetation patterns (Gresswell 1999). Techniques used to manage fires, such as fire lines and post-fire rehabilitation activities, can increase fine sediment delivery to streams, negatively impacting stream biota (McCormick et al. 2010).

1.5.7 Herbicide Applications

Herbicide is used in two main programs: (1) control of roadside vegetation and (2) control of invasive species (note that these are often, but not always, the same). Typical herbicides, such as 2,4D and glyphosate (Roundup), are often used by counties and the National Forest Service (Colborn and Short 1999). Active vegetation control is also practiced by NPS units within park boundaries. Some herbicides are extremely toxic to aquatic invertebrates and are not legally applicable to areas where run-off will enter waterways, usually clearly labeled on herbicide labels. Additional impacts due to treated vegetation entering the stream as leaf litter are unstudied and unknown to our knowledge. Knowledge of impacts other stream biota (fish and amphibians) is also lacking.

1.5.8 Marijuana Farming

Illegal marijuana cultivation is occurring in Whiskeytown National Recreation Area and Redwood National and State Parks. Other network parks have concerns that marijuana cultivation may soon occur within their park boundaries. Security concerns with scientists working in and around areas of illegal cultivation have prevented detailed studies(Joyce 1999), but stream ecosystem impacts will resemble those from legal agriculture, including (1) water diversion, (2) increased sediments, and (3) eutrophication through the use of fertilizers (Allan 2004).

1.5.9 Non-native and Introduced Species

Introduced, non-native species can cause large changes to native biodiversity and trophic dynamics of aquatic ecosystems (Vander Zanden et al. 1999, Knapp et al. 2001, Parker et al. 2001, Schindler and Parker 2002, Boersma et al. 2006). In Klamath Network parks, historical introductions of rainbow trout (*Onchorhynchus mykiss*), brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) are potential ecosystem stressors. Other invasives include both vertebrate (e.g., American bullfrogs [*Rana catesbeiana*]) and invertebrate (e.g., New Zealand mudsnails [*Potamopyrgus antipodarum*]) taxa. Considerable threats also exist from emerging diseases, such as chytrid fungus (*Batrachochytrium dendrobatidis*), which affects native amphibians and whirling disease (*Myxobolus cerebralis*) that impacts native salmonids. Non-native plants in riparian zones can also alter structure (e.g., Salt cedar [*Tamarix* sp.] in the American Southwest). Threats in the Klamath region include Reed Canary Grass (*Phalaris arundinacea*), Himalayan blackberry (*Rubus armeniacus*), and the aquatic macrophyte water hyacinth (*Eichhornia crassipes*).

1.5.10 Non-recreational Land Use Practices within and External to Parks

Land use practices that include potential stressors to Klamath Network parks include: park operations (e.g., construction and road maintenance), water withdrawal, dam operations, fire management, timber harvest, and geothermal explorations (Hoffman and Sarr 2007). Potential pathways include increased sediments, pollutants, and hydrologic changes from direct and indirect impacts (Allan 2004).

1.5.11 Septic Field Leaching

Leaching of septic field sewage is a potential stressor to park waterways both from septic systems within the park and external to the park. Sewage contains nutrients (resulting in eutrophication) and bacterial or viral diseases (Vaughn et al. 1983, Yates 1985).

1.5.12 Temperature Impairment

Excessively high temperatures can be extremely detrimental to aquatic biota. Moreover, temperature determines the ability for water to maintain high dissolved oxygen concentrations, which affects many aquatic organisms. Salmonid species, in particular, are sensitive to stress caused by increased temperature, both in the oxygen content of the water and overall stress (e.g., at higher temperatures salmonids exhibit a reduced immune response to disease [Sanders et al. 1978]). Temperature is also critical for amphibian development and reproduction, with the tailed frog, *Ascaphus truei,* having some of the lowest tolerances to increased temperature of amphibians in North America (Bury 2008). Temperature is also a cue in the development and hatching of aquatic insects, so that under alteration, emergence and life cycles are offset with historical norms. This can cause insects to emerge too early, so that the adult stage is exposed to winter storms or other extreme events causing mortality (Vinson 2001). Projected effects of climate change on summer air temperatures, the nature of riparian vegetation, and the timing of snowmelt will likely all have interactive effects on the levels of summer low flows and peak water temperatures.

1.5.13 Visitor Recreational Activities

Potentially damaging recreational uses include improper camping, pack-stock use, boating, and fishing. Recreational impacts include mechanisms from the other stressor categories above. For example, camping can cause the input of nutrients from improper disposal of camper waste, or anglers and boat use can contribute to introduction and dispersal of non-native species.

1.6 Vital Signs Objectives

The programmatic goals of the Klamath Network are (from Sarr et al. 2007):

- To determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better informed decisions
- To provide early warning of abnormal conditions and impairment of selected resources to help develop effective mitigation measures and reduce costs of management
- To provide data to foster better understanding of the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other altered environments
- To provide data to meet legal and Congressional mandates related to natural resource protection and visitor enjoyment
- To provide means of measuring progress towards performance goals
- To support park interpretation and educational programs

Applications of these programmatic goals, and the specific wadeable streams objectives to meet these goals were largely determined at scoping meetings with Network ecologists, USGS specialists, and park resource experts. Refinement based on feasibility, logistics, and budgetary realities determined during the pilot project (Appendix A) were also taken into consideration.

1.6.1 Monitoring Objectives

Objective 1: Determine the status and trends of ecological conditions in Klamath Network wadeable streams. Through careful selection of indicators, we can inform managers to help with decision making, warn of abnormal conditions, and gain understanding of the park ecosystems. Through quality control, data analysis, and multiple reporting formats, we can meet legal requirements, measure performance goal progress, and help education programs. Together, this will meet the Network’s programmatic goals.

To meet this goal, several terms must be clearly defined:

- “Ecological condition” – From the EPA Report on the Environment, “ecological condition” is defined as “the state of the physical, chemical and biological characteristics of the environment, and the processes and interactions that connect them (U.S. EPA 2008).”
- “Status” – “defined as some statistic (e.g., a mean or proportion) of a parameter over all monitoring sites within a single or well-bounded window of time. Status will always have some measure of statistical precision (e.g., a confidence interval, standard error, variance)…(Sarr et al. 2007).”
- “Trend” – “defined as a non-cyclic, directional change in a response measure that can be with or without pattern (Urquhart et al. 1998).”

The very definition of ecological condition speaks to the need for integrating indicators from a range of physical, chemical, and biological characteristics.

Objective 2: Assist parks with "impaired quality waters," also known as "303d" lists as defined by the Clean Water Act. The method of assisting should be in two functions:

> a. Gather information on the pollutants that exceed standards that will assist the park and the state to design specific pollution prevention or remediation programs through Total Maximum Daily Loads.
>
> b. Determine whether the overall program goal of improved water quality is being achieved after the implementation of effective pollution control actions.

Currently, there are two Clean Water Act, Section 303d listed (hereafter simply 303d) sites within Redwood National and State Parks: Redwood Creek is listed for water temperature (> 5°F above natural levels), and the Klamath River is listed for nutrients ("biostimulatory substances;" above levels that cause nuisance or adverse effects) and water temperature (North Coast Regional Water Quality Control Board, 2010). Redwood Creek is currently being monitored by the park; however, the Network will assist the park by implementing this protocol at two sites within the affected reaches of Redwood Creek. The Klamath River is intensively monitored by other agencies, both governmental and non-governmental, and its large size precludes it from being applicable to this protocol (Hoffman and Sarr 2007).

Objective 3: Assist parks with monitoring of "Outstanding National Resource Waters" or Tier 3 waters as defined by the Clean Water Act. The method of assisting should be in two functions:

> a. Allow characterization of existing water quality and to identify changes or trends in water quality over time.
>
> b. Identification of specific existing or emerging water quality problems.

Currently, there are no Outstanding National Resource Waters in any of the parks of the Klamath Network. This specific objective and functions dictated by the Water Resources Division are met by monitoring the lakes and streams of the Network parks.

1.6.2 Measurable Objectives

Measurable objectives to meet the objectives of this protocol (see relevant SOPs for details) include:

- Use probabilistic sampling to establish accessible wadeable stream reaches within the five park units covered by this protocol.
- Measure physical environment parameters at each wadeable stream reach: substrate composition, depth, gradient, discharge, stream width, bank height, etc.
- Collect core water quality parameters in a single well mixed section of each stream reach: dissolved oxygen, temperature, specific conductivity, turbidity, and pH.
- Measure stream water anions, cations, and nutrients along each stream reach every three sampling periods.
- Collect a composite of 11 algal samples to determine periphyton biomass at each stream reach.
- Collect quantitative samples of reach-wide benthic macroinvertebrates.

- Conduct Visual Encounter Surveys for amphibians to develop species lists.
- Survey for fish populations using electrofishing to determine presence and catch per unit effort of fish populations.
- Photograph stream reaches in a systematic manner so images can provide visual comparisons over time.
- Develop and maintain a database and associated metadata derived from the sampling procedures.
- In an Annual Report, report status of key parameters for each park surveyed that year.
- Write Analysis and Synthesis reports every 3 years that explore relevant topics in depth. Specifically, individual Analysis and Synthesis reports will detail trends in core parameters and species composition and abundances, explore data patterns to relate stressors to observed trends, utilize observed/expected models for species assemblages, and utilize indices of biotic and ecological integrity.

2.0 Sampling Design

We use the unified terminology presented in McDonald (2003) for monitoring programs designed for estimating status and trends in environmental indicators. The sampling design describes both how sample units are selected from the sampled population (membership design) and how those units are visited over time (revisit design). Careful consideration of the trade-offs and constraints in designing sampling schemes over long time periods and vast spatial areas are imperative for protocol success in meeting objectives.

This protocol covers five of the six Klamath Network parks: Crater Lake National Park, Oregon Caves National Monument, Redwood National and State Parks, Lassen Volcanic National Park, and Whiskeytown National Recreation Area. Lava Beds National Monument, the only Klamath Park unit not covered by this protocol, has no perennial streams.

In brief, Klamath Network streams are sampled using an always revisit [1-0] design (McDonald 2003) and each stream reach and park is sampled in the summer months every 3 years. In each park, between 10 and 15 streams are probabilistically selected using a spatially balanced design (the exception to this is Oregon Caves National Monument, with only a single stream). In each selected stream, between two and three stream reaches are probabilistically chosen to be sampled every 3 years. Each park additionally has between one and two judgment streams selected by park specialists (section 2.1.1). Not every park is sampled every year; in a three year rotation, year one is spent sampling lakes, year two is spent sampling streams in three parks, and year three is spent sampling streams in two parks not yet sampled. In year four, the pattern repeats.

2.1 Rationale for Selection of Sampling Design

An always revisit design was chosen for several reasons. It: (1) maximizes the ability to detect trends, (2) reduces logistical and budgetary issues of establishing new sampling reaches and (3) simplifies data analysis. Other more complex sampling designs, such as a split panel design with rotating panels with different revisit schedules, were carefully considered but were not chosen for the following reasons: (1) methodology integrating different panels in long-term trend analysis is not clear, (2) considerable expense is incurred in land-marking an increasing number of safe and accessible stream reaches, and (3) low numbers of perennial streams in *most* Network parks negates the need for increasing spatial coverage with additional panels.

The Klamath Network has worked closely with statisticians and water quality professionals from Colorado State University, University of Idaho, Montana State University, and the National Park Service Water Resource Division to ensure a sampling design that provides the greatest ability to determine status and detect trends.

2.1.1 Judgment Sites

In addition to probabilistic reaches, judgment reaches will also be monitored. Judgment reaches, as defined in Sarr et al. (2007), comprised of sites that are subjectively selected because either: (1) they have a history of sampling, (2) they are accessible, or (3) the target population is very specialized and/or unique. Another justification is that certain reaches may be facing specific threats and monitoring for these threats is best concentrated at such reaches. Continuation of existing or focused monitoring for special populations or threats is valuable, but because such reaches are not probabilistic, they can only be used to make inferences to the specific reach in question. Recognizing these caveats, judgment reaches were minimized and were selected with input from park specialists at protocol scoping meetings.

Crater Lake National Park

- Sun Creek: This stream is habitat where the federally listed bull trout (*S. confluentus*) is readily accessible to the public along a major access road, and is the site of intensive ecological restoration.

Lassen Volcanic National Park

- Hot Springs Creek: This stream is representative of geothermally-influenced streams that make up one of the unusual features of the park. It is also subject to impacts from existing park infrastructure, including buildings, leach fields, and visitor use. An unusual fen is also a portion of the riparian zone of this creek.

Oregon Caves National Monument

- Cave Creek: This stream flows through the ORCA cave-complex, has a history of monitoring, is a central feature of the park, and is subject to visitor use.

Redwood National and State Parks

- Godwood Creek: This stream is relatively pristine and is the only stream through the roadless, old-growth area in RNSP.
- Redwood Creek: This creek is a 303(d) listing for impairment in temperature and sediments, has been the subject of active restoration, and is habitat to a number of anadromous fish.

Whiskeytown National Recreation Area

- Willow Creek: This creek has historically been on 303(d) lists for impairment from acid mine drainages, with heavy metal accumulation, and has a history of monitoring.

2.2 Target Population

The target population, as defined by Irwin (2008), is “the larger universe of all possible values (bounded in time and space) that one is sampling from and wishes to make statistical inference (conclusions) about.” For this protocol, temporal and spatial frame errors (over- and under-coverage) are minimized to justify that the probabilistically sampled population is the same as the target population. In the Klamath Network, the target population per strict definition is all possible values sampled during “index” periods, during daylight hours, and wadeable streams fitting the following criteria:

- Perennial – This selection criterion is applied to remove habitats that are influenced by seasonal desiccation which could mask other stressors of interest and add excessive variation to the parameters. It also ensures that data collection can always occur at the sites, assisting in data completion goals (SOP #19: Quality Assurance Project Plan).
- Less than 1000 m from a travelable road or trail – This selection criterion reduces logistical constraints to field crews, such as travel time, to ensure that each site can be sampled in the allotted time frame for achieving sampling objectives.
- Stream gradients with slope less than 15 percent – This selection criterion ensures crew safety and that access to streams is doable.

In defining the target population, two additional terms must be defined: (1) wadeable stream are defined as 1^{st} through 5^{th} order streams based on the Strahler stream order (Strahler 1957). In the Klamath Network, the Klamath River (at the mouth in REDW) is an 8^{th} order stream, the Smith River is 6^{th} order, and Redwood Creek is on the cusp at 5^{th} order. However, some of the remaining streams may be unsafe for field crews to enter depending on observed conditions. For example, lower Redwood Creek is a 5^{th} order river, but winter and spring debris-laden high flows prohibit safe entry. Also, streams portions may include unwadeable pool habitats, although the rest of the stream may be wadeable.

The second term needing defining are “index” periods. Index periods are timing of stream base flows, with the concept that sampling over the broad index period are comparable. In California, index periods are broadly defined based on elevation and latitude, so that northern areas (including the Klamath Network) are sampled in “late summer.” There is no defined index period for Oregon; however, the Pacific Northwest Aquatic Monitoring Partnership (Hayslip 2007) defines index periods as being from July 1^{st} to October 15^{th} for the Pacific Northwest. This protocol adopts this as the index period for the Klamath Network.

An important concept concerning the target population is the limitation of inference that can be made to the stream based on data collected under these conditions. Clearly, certain parameters vary on a daily, seasonal, and annual basis (e.g., water temperature). A single point in time measurement of water temperature cannot be taken as indicative of water temperature outside the bounds of the temporal target population. However, certain stream parameters integrate over large temporal scales. For instance, aquatic macroinvertebrates assemblages include both long- and short-lived taxa, so that short-lived invertebrates respond to recent disturbance, and long-lived taxa are sensitive to events that may have occurred the past year. Likewise, severe disturbance, such as debris flows will be manifested in the stream invertebrate assemblage for years after the initial disturbance. Additionally, changes in pool/riffle/glide macrohabitat respond over yearly time frames, whereas reach-wide characteristics (e.g., sinuosity) respond over decadal or longer timespans. Hence, although some stream environmental characteristics are sampled at a single point in time within the target population, they provide valuable information outside the temporal span of the target population.

2.3 Stream and Sample Reach Selection

A two-stage design is used to select sample reaches fitting the criteria used to define the target population. Streams are selected using a Generalized Random Tessellation Stratified design (GRTS – pronounced “grits”) (Stevens and Olsen 1999, 2004). This design employs a systematic sampling technique to obtain a spatially balanced probabilistic sample. A particularly attractive feature of GRTS is the ability to accommodate unequal probability sampling by allowing the probability of individual sampling units to vary. In the case of the wadeable stream selection, two GRTS selection processes ("draws") are performed. For the first stage, the first draw is performed on all streams (excluding *a priori* judgment streams, and the single non-wadeable river [the Klamath River]). This procedure also produces a spatially balanced over-sample (i.e., a list of additional streams to sample if streams need to be replaced or added). For the second stage, a second draw is taken from *within* the selected streams, to produce spatially balanced reaches to be sampled within the stream. Within each stream, two or three reaches (depending on the park unit) are selected, also with oversample reaches. If a specific stream selected does not have reaches fitting the criteria, an oversample stream will be utilized. Since the GRTS method creates spatially balanced and dispersed sample reaches, it minimizes spatial autocorrelation and maximizes the effective sample size for a given number of stream reaches, thereby helping to increase statistical power. We use a spatially balanced design because a simple random sample, although a conceptually easy and statistically simple to implement, can produce a clustered site distribution.

The National Hydrography Dataset (NHD), containing geospatial hydrologic data that enumerate and identify all wadeable stream habitats within the park, was used to populate the Geographical Information System (GIS) database for running the GRTS draw with a custom script in the statistical software program *R*. The *R* script "spsurvey" was used to draw the stream list from remaining locations in each park (Kincaid 2006). Table 2 provides a summary of the numbers and proportions of stream kilometers available for inclusion, excluded by the criteria, and total number of reaches to be sampled in the protocol.

Step by step site selection procedures using GRTS are further outlined in SOP #3: Site Selection, as are the results of the GRTS draw. However, the process of using the computer program *R* is beyond the scope of this protocol. Note however, that SOP #3: Site Selection should only have to be used at the initiation of the protocol prior to the first field season and will not need to be done prior to every field season. It is provided to give the field crews and incoming Project Leads the proper context for the survey design and rationale. It is also possible that a new GRTS draw may be necessary if the sampling population changes over time (as in Irwin 2008).

Table 3. Comparison of total streams, stream kilometers (km), and number of streams and stream reaches to be sampled through protocol implementation.

Park Unit	Total number of stream km in park	Number of stream km included in target population	Number of named streams	Number of streams to be sampled	Total number of stream reaches
Crater Lake National Park	198.94	105.33	29	15	30
Lassen Volcanic National Park	101.34	71.63	18	15	30
Redwood National and State Parks	382.35	180.23	57	15	30
Whiskeytown National Recreation Area	74.19	54.21	11	10	30

2.4 Frequency and Timing of Sampling

2.4.1 Sample Frequency

Sampling of wadeable streams occurs every 2 out of 3 years as a part of the overall design of integrated aquatic communities and water quality (Table 3). In the single year between stream sampling, mountain lakes and ponds (covered in a separate protocol) will be implemented. In stream sampling years, a low elevation park (WHIS, REDW) is paired with a high elevation park (CRLA, LAVO). Early season, sampling will first occur in the lower elevation park, with late season sampling in the high elevation park.

Table 3. Temporal revisit design of integrated water quality and aquatic communities for both lakes and wadeable streams. After 2015, the pattern continues.

Habitat type	Park units	2010	2011	2012	2013	2014	2015
Lakes	Lassen Volcanic National Park	X			X		
	Crater Lake National Park	X			X		
	Redwood National and State Parks	X			X		
Wadeable Streams	Whiskeytown National Recreation Area		X			X	
	Lassen Volcanic National Park		X			X	
	Oregon Caves National Monument		X			X	
Wadeable Streams	Redwood National and State Parks			X			X
	Crater Lake National Park			X			X

2.4.2 Sample Timing

Sample timing encompasses both the timing of sampling efforts across years and the time of day that sampling is accomplished, but also considers issues of comparability and logistical scheduling. Timing of sampling efforts at sample reaches across years will be kept as constant as logistically possible. This reduces inter-annual variation caused by phenological characteristics of the sampled streams. For example, if Willow Creek (WHIS) is sampled on 15th July 2011, the repeat visit will occur around the 10th-20th July 2014. Sampling Willow Creek later in the field season, (e.g., late August or early September) would introduce variation from changes in insect emergence and lower flows. After the first field season, dates for all sample reaches will be used for planning the next sampling period in perpetuity (Figure 5).

Another aspect of sample timing that can affect results is diurnal shifts in parameters. For instance, primary production may peak during high noon, so that dissolved oxygen correspondingly increases at midday. Measurements of dissolved oxygen taken at midday will differ from values taken at dawn. Amphibian behavioral differences from mid-day to dusk activities can also affect detectability during surveys. To reduce variability in these parameters, field crews will perform all sampling during standard daylight hours; generally between 9AM and 4PM. Clearly, logistics of reach access will dictate actual start times, but crews cannot start sampling pre-dawn. Time of sampling will be recorded for measured parameters to help in the interpretation of variation relative to time of sampling.

However, by adherence to “index” periods for aquatic macroinvertebrates, broad comparability across years, parks, and stream reaches for macroinvertebrate assessment techniques is defensible. To what degree these broad comparisons are valid for other measurements (e.g., water chemistry, amphibians) is unknown and under studied.

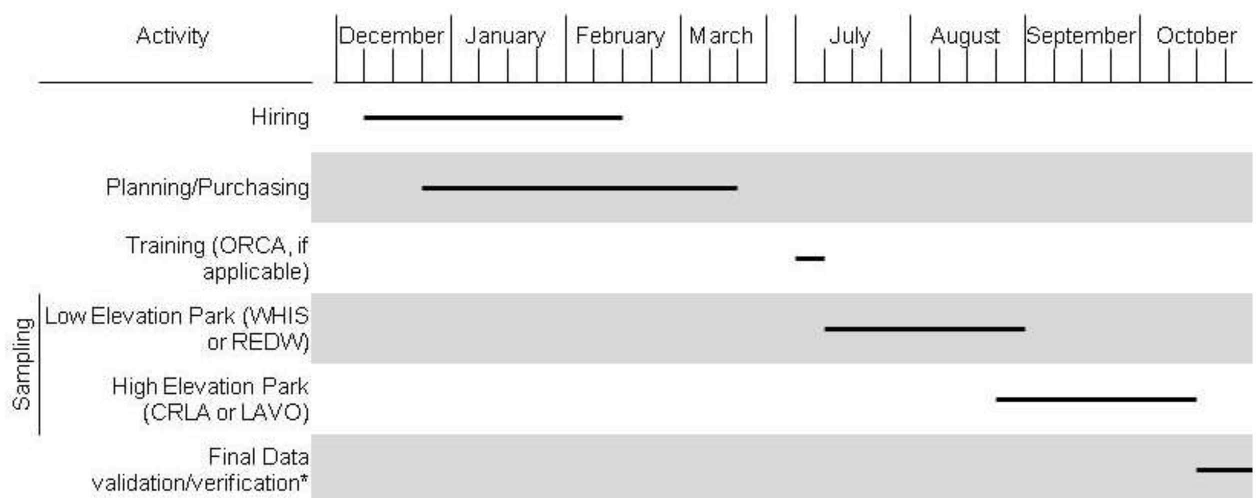

Figure 5. Timeline for hiring, planning, training and sampling. *Data validation and verification is done by Crew Leader throughout the project, final validation and verification is by Project Lead.

2.5 Rationale for Selection of Parameters

Each parameter to be measured was chosen for the following reasons:

- It directly or indirectly addresses protocol objectives.
- It is mandated by National Park Service Water Resources Division.
- It can be used to derive an index or indices that address protocol objectives.
- It places other parameters in a context to better address protocol objectives.
- It assists in making correlative statements between response variables and stressors.
- It is a cost-effective alternative to other parameters.

In this context, parameters are defined as features allowing quantitative or semiquantitative measurements (e.g., numerical, ordinal, or categorical data) through field visits or laboratory analyses. Table 3 provides a summary overview of parameters to be monitored; the text below explores the context and rationale for each parameter in more detail.

2.5.1 Core Parameters

The core parameters represent a set of water quality attributes that will be measured as part of all NPS Water Resource Division funded water quality monitoring protocols. As such, these attributes contribute some measure of consistency and comparability of water quality conditions among multiple NPS monitoring programs (NPS 2002). However, the use of the word “core” does not imply that these parameters are more or less important than other parameters.

Water temperature is a critical variable controlling many ecosystem processes, both physical and biological, and it can impact almost all functions within an ecosystem (Allan and Castillo 2007). Water temperature is also a critical parameter for tracking climate change’s manifestation in these important park ecosystems.

Water pH, the measure of water hydrogen ion concentration, is a critical attribute of any water body with many physical and biological effects. Low pH (<7) indicates acidic waters and high pH (>7) indicates basic water. Most aquatic species occur within specific habitat envelopes of pH conditions and changes to pH will likely result in changes in species assemblages. In addition, the pH determines the solubility of many heavy metals, which has negative impacts on invertebrate biodiversity (Wiederholm 1984, Allan and Castillo 2007).

Table 3. Parameters to be measured under this protocol. See SOPs for more details. [1] Water Quality "Sonde" is the industry standard term for Water Quality Probe.

	Parameter	SOP #	Methodology summary
Water chemistry - Field			
	Dissolved oxygen	7	Multiprobe water quality sonde cross section[1]
	pH		
	Specific conductivity		
	Temperature		
	Turbidity		
	Acid neutralizing capability	8	Field titration kit
Water chemistry - Lab			
	Anions (Cl, SO4)	8	Ion chromatography
	Cations (Na, Ca, K, Mg)		Spectrophotometry
	Dissolved organic carbon		Combustion-Infrared
	Total nitrogen		Persulfate Digestion
	Total phosphorous		Spectrophotometry, Persulfate, sulfuric acid digestion
Stream environment			
	Riparian	14	Transect based, estimates of coverage
	Dominant trees	14	Visual estimates, laser range finder
	Channel morphology	6,12	Reach and transect based direct measurements
	Shading	12	Transect based spherical densiometer
	Substrate	12	Transect based cross sections
	Discharge	10	Velocity meter cross sections
Aquatic Community			
	Algal biomass	11	Ash free dry mass from cobble scrubbing
	Benthic macroinvertebrates	9	Reach wide benthos
	Amphibians	15	Visual encounter surveys, electrofishing
	Fish	15	Electrofishing

Specific conductance, or simply *conductance*, the ability of a water body to conduct an electric current, is directly correlated with dissolved ion concentrations in water bodies. In essence, the "purer" the water, the lower the concentrations of dissolved salts and thus the lower the conductance. Changes in conductance suggest changes in major ions or nutrients, such as potassium, calcium, and other anions and cations.

Dissolved oxygen, a critical element for the aquatic biota, is closely linked to physical and biological processes. For instance, respiration, photosynthesis, and atmospheric exchange (through turbulence in rapids and riffles) are the principle processes that affect or are affected by dissolved oxygen concentrations. In addition to high water temperatures, high microbial activity, driven by organic pollution, drives demand for dissolved oxygen resulting in anoxic conditions. High oxygen levels are especially critical for the metabolism of aquatic insect and salmonid eggs.

Discharge is a fundamental indicator of the conditions of a stream at the time of sampling. Discharge is also used as a grouping factor in categorizing streams and as a potential co-variable explaining temporal variation. Discharge and the timing of peak and low discharge events is also an expected response variable to climate change.

2.5.2 Water Chemistry Parameters

Water chemistry parameters are indicative of ecosystem quality and have a profound effect on aquatic organisms. By themselves, they can equate to the generalized notion of "water quality," indicative of water pollution or a stressor and effect (for example, high nutrient load leading to eutrophication). Analysis of water chemical characteristics is fundamental to effective water quality monitoring.

Acid Neutralizing Capacity (ANC) is the resistance of water bodies to acidification. It is measured in the field using unfiltered water (note: when done on filtered water, it is termed Alkalinity; when on unfiltered water it is ANC). Here, we perform the tests on unfiltered water to obtain the actual ANC value for a site. As a measure of buffering capacities of streams, it is indicative of resistance to pH declines owing to acid stream drainages, as well as natural processes or other anthropogenic stressors.

Anions/Cations being monitored include the two predominant anions (negatively charged ions – SO_4^{2-} and Cl^-) and four cations (positively charged ions – Ca^{2+}, Na^+, K^+, and Mg^{2+}). These six ions, along with carbonates (estimated with the ANC measurement), make up most of the ions in stream water. These ions are important indicators of the watershed context of the stream, with different ion concentrations reflecting variation in geology, vegetation, and weathering processes. However, SO_4^{2-} is also common as an indicator of pollution (e.g., from mining waste or fertilizers). It is important to note that SO_4^{2-} is common in volcanic regions such as CRLA and LAVO.

Dissolved organic carbon is a measure of detritus in the water column. Sources of dissolved organic carbon (DOC) can be from autochthonous (within the stream) processes through extracellular release by algae or senescing organisms or bacterial degradation or allochthonous (terrestrial) processes (e.g., leaf litter breakdown carried into the lake by wind or water). Utilization and uptake of DOC by bacteria and periphyton is enhanced by higher temperatures and light; hence decreasing trends in DOC may indicate climate change, although acidification is also a potential cause in decreasing DOC (Schindler et al. 1992, Wetzel 2001).

Nutrients include the dominant forms of nitrogen and phosphorous. Both elements may be limiting nutrients to aquatic ecosystems, controlling ecosystem productivity, as well as being indicators of eutrophication caused by external stressors (e.g., atmospheric deposition or visitor use activities). Nitrogen will be measured as total dissolved nitrogen.

Similar to nitrogen, phosphorous is an important limiting nutrient and can be the most limiting. We will be monitoring total dissolved phosphorous.

Turbidity is a measure of water clarity. Water with high turbidity (e.g., low clarity) indicates either high amounts of suspended solids (i.e., siltation) or high productivity.

2.5.3 Stream Environmental Parameters

Environmental measurements serve as co-variables to help us understand patterns in the aquatic communities and also as monitoring parameters themselves. As co-variables, environmental variables are useful in predicting presence/absence of organisms based on habitat heterogeneity or on total habitat availability and may help explain important spatial variation in other parameters of interest across the sampling frame. They are important components of aquatic resource monitoring because these characteristics help describe the context or template for ecosystem function and condition (Southwood 1977, Warren 1979, Frissell et al. 1986, Larson et al. 1994, 1999). Additionally, as monitoring parameters of their own, trends in specific parameters (e.g., increases in the percent of fine sediments) can indicate a stressor such as land use or visitor impacts. This group of parameters also includes estimates of nearby human influences.

Environmental parameters as sampled either as reach-wide characteristics or transect based characteristics.

2.5.3.1 Transect Based Environmental Parameters

Bank measurements – This includes left and right bank angles, undercut distance, stream width, width of bars (if present), bankfull width, bankfull height, and incised height. These offer basic geomorphological measurements of the stream channel, providing information on bank stability, habitat availability, and fish cover.

Canopy cover – A measure of shading over the stream, canopy cover indicates the amount of vegetative overstory. Highly shaded streams are likely to be dominated by allochthonous inputs, whereas streams without cover are more likely to be driven by autochthonous production. Streams without cover are also more likely to exhibit greater temperatures and larger diel shifts.

Stream substrate, depth, and embeddedness – these points, measured at the left bank, 25% width, 50% width, 75% width, and right bank, also give basic measures of habitat type, availability, and sediment deposition.

Human influence – Presence/absence and proximity of a suite of human influences (e.g., buildings, roads, pipes, trash, etc.) give indicates of near-field human impacts.

Fish/Amphibian Cover – Categorical area estimates provide information on macroscale cover (e.g., filamentous algae, macrophytes, woody debris, etc.) for aquatic vertebrates. Cover is important as refuge from predation and cooler temperatures.

Riparian estimates – Categorical area estimates of vegetation classes (canopy, understory, and ground cover) along with broad type of vegetation (e.g., deciduous or coniferous) provides information about riparian zone structure and function.

Woody debris – Large woody debris storage and retention is a common response variable in degraded versus pristine streams. Woody debris provides habitat for invertebrates and vertebrates and can play a role in channel structure (e.g., logjams).

Dominant trees – Dominant trees are the largest riparian tree, are important components of the riparian zone structure, and provide habitat for terrestrial vertebrates. The type, height, distance from stream, and categorical estimate of diameter breast height are recorded. These trees are called "legacy" trees in the EPA terminology, whereas we use the term "dominant" to coincide with the KLMN Vegetation Monitoring Protocol.

Invasive species – Invasive plant species in the riparian zone are recorded as important components.

2.5.3.2 Reach-wide Environmental Parameters
Slope – Stream gradient is a fundamental aspect of stream geomorphology and in structuring the stream community.

Discharge – Discharge is taken at a single point in the stream channel but is representative of the entire stream reach. It is also a fundamental component of stream ecosystems, structuring both the physical and biological elements.

Channel variables – Channel patterns (i.e., braided or not), percent channel constrained, constraining features, evidence of recent flooding, and valley width are all recorded as co-variables.

2.5.4 Aquatic Communities
Aquatic communities are made up of different taxonomic components, spanning the spectrum of functional roles: primary production, consumption, predation, and decay. Any one taxonomic component (e.g., macroinvertebrates) is not a "community," but rather an assemblage that makes up an important part of the entire aquatic community. By sampling all aspects of the aquatic community, we will effectively be sampling the stream food chain (or trophic structure), aimed at determining status and trends in stream functional ecology. By examining the whole aquatic ecosystem, interactions between organisms can be better understood so that predictive models of how park ecosystems respond to specific stressors or extirpations can be evaluated (Agrawal et al. 2007).

Aquatic communities are important components of aquatic ecosystems that are determined by and sensitive to the conditions of the habitats within which they reside (Loeb and Spacie 1994). Part of their utility as monitoring indicators is that each assemblage can react individually to different stressors. For example, increasing sediment inputs can create negative responses in fish due to clogging of gills or smothering of eggs, whereas certain insects (e.g., certain Chironomidae midges) will respond positively to increases in habitat for burrowing. An additional advantage is that aquatic communities integrate responses to stressors over time, with some components responding rapidly to changes and others responding gradually to longer-term stressors. For instance, benthic macroinvertebrates act as continuous monitors of water quality issues, so that even a point-in-time measurement can provide information about seasonal or annual trends without the need for continuous sampling (Hawkes 1979).

Integrated biological sampling provides cost-effective monitoring of aquatic resources, when compared to other types of monitoring. A review of cost/benefits comparing biological monitoring to physical, chemistry, and toxicity monitoring showed the greatest gain and understanding from using biomonitoring alone, and that when combined with physical and chemical monitoring, provided the best overall ecosystem assessment (Brinkhurst 1996).

Algal biomass is a measure of stream productivity driven by autochthonous production. High values can indicate nutrient enrichment. In general, high values should also be positively correlated with higher order streams with large wetted widths and negatively correlated with increasing riparian cover and stream shading. Abnormal conditions from this pattern can signal impacts. Biomass is measured as the standing crop of periphyton (algae growing on any submerged surface).

Benthic macroinvertebrates have a rich scientific history as biomonitoring tools (Rosenberg and Resh 1993). Changes in macroinvertebrate assemblages have been successfully demonstrated as indication of ecological impairment (e.g., Lenat et al. 1981, Rosenberg et al. 1986). Benthic macroinvertebrates form the basis of predictive models of impairment, using O/E (observed to expected ratios), comparing observed to expected conditions (assuming no impact). Such predictive models include the River Invertebrate Prediction and Classification System (RIVPACS, Wright et al. 1989) models and also integrated multi-metric IBIs (index of biological integrity) (Karr and Chu 1999).

Amphibians are perhaps the premiere “early-warning detection system,” being exceptionally sensitive to changes in water chemistry, chemical pollution, and introduced pathogens. Amphibians world-wide are experiencing population declines due to a large number of distinct and interacting stressors (e.g., exotic species, impaired habitat, pollutants, climate change, etc.). For this reason, many populations are currently imperiled and necessitate monitoring for inherent conservation reasons. Integrated into stream monitoring, amphibians represent signals of introduced exotic species (Stead et al. 2005, Fellers et al. 2008), emerging wildlife diseases (Collins and Storfer 2003), and declining ecological integrity (Knapp et al. 2005).

Fish, as long-lived top predators in stream ecosystems, serve as integrated monitors of the stream ecosystem. Fish have the advantage of migrating large distances, so that fish responses also integrate over a larger spatial scale (including anadromous fish from the Pacific Ocean). As threatened species, the bull trout, Chinook, and Coho salmon are of inherent interest. Given that designated beneficial uses of Klamath Network streams include Coldwater Fisheries, monitoring fish assemblages provides valuable information in managing stream ecosystems.

2.5.5 Derived and Integrated Metrics/Indices
From the various classes of monitoring parameters, we will derive a number of useful metrics and indices for assessments of status and trend, as well as data exploration. Most metrics will be based on EPA protocols. Some metrics are used as simple correlative parameters (e.g., habitat volume) for classification or data exploration; other metrics serve as explanatory variables (e.g., shoreline development), which should equate to habitat complexity (Wetzel 2001). The actual calculation of these metrics is detailed in SOP #22: Data Analysis and Analysis.

Shannon index and *Evenness* are classical measures of diversity that incorporate dominance, or lack of dominance, of taxonomic groups. We use these in addition to normal measures of diversity, such as basic species richness, because macroinvertebrate responses to stressors are often manifested as dominance changes, with one or two species dominating the assemblage. In these cases, Shannon index and Evenness may provide more power to evaluate stressor response of the aquatic community.

Hilsenhoff Biotic Index is a weighted average of tolerance values derived from empirical observations of macroinvertebrate responses to pollution (Hilsenhoff 1987, 1988). Since these responses have been extended to a variety of impacts, the Hilsenhoff Biotic Index is a useful way of examining macroinvertebrate changes to stressors.

Multi-metric Index (MMI) is a traditional approach used to assess stream health based on stream assemblages (Stoddard et al. 2005). This provides managers with a single value, integrating multiple components of the assemblage, ranging from 0 to 100, with high scores indicating undisturbed ecosystems, and low scores indicating impairment. We will use combinations of MMI (Also called Indices of Biological Integrity, IBI) developed by the EPA and state (CA and OR) monitoring agencies to assess stream health both on fish assemblages (EPA only) and invertebrate assemblages (EPA and State).

O/E Index is a complementary approach using a predictive model of expected taxonomic diversity, specific to macroinvertebrates, drawn from reference sites across multiple, natural gradients (Hawkins et al. 2000). Using predictor variables, such as elevation, stream size, gradient, latitude, and longitude, expected taxonomic diversity of macroinvertebrates can be predicted. The observed, sampled diversity is then used in the O/E ratio, so that a value over 1.0 indicate greater than expected diversity (undisturbed) and values under 1.0 indicate impairment.

Physical Habitat Summary Metrics have been developed as part of the EPA EMAP protocols for quantifying physical habitat in wadeable streams (Kaufmann et al. 1999). Metrics include summation and averages for riparian shading, fish and amphibian cover, and total habitat availability.

2.6 Power Analysis

A power analysis is a valuable step to assess whether the proposed sampling effort in terms of number of wadeable streams sampled per park unit over time is sufficient for detecting long-term trends in environmental indicators. Power is a function of the sample size (number of streams), number of years of sampling, variance of the indicator, and type 1 error (probability of detecting a trend when in fact there is not one). The variance of an indicator is typically unknown and is therefore estimated from available pilot data. For the indicators of interest in this protocol, unfortunately very few long-term data are available at this point. However, we use available macroinvertebrate data from PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program (PIBO) to explore the power to detect annual trends in the observed to expected ratios, one of the primary bioassessment tools.

We make the assumption that the variability inherent in the PIBO data is representative of that within the sampling frames of the five parks covered under the KLMN wadeable streams protocol. In this protocol, there are a combination of probabilistic and judgment (non-random) streams selected for monitoring. We only consider how to model trend within the probabilistically selected sites which provide park-wide inferences about long-term trends.

In order to perform a power analysis for univariate trend, a model must be assumed for the future data. We adopt the linear model presented in Urquhart et al. (1998). The model is as follows $\log(Y_{ij}) = \mu + S_i + T_j + E_{ij}$ where Y_{ij} is the observed characteristic of interest (e.g., average observed to expected ratio) for stream *i* in year *j*, $S_i \sim N(0, \sigma^2_{STREAM})$, $T_j \sim N(0, \sigma^2_{YEAR})$, $E_{ij} \sim N(0, \sigma^2_{RESIDUAL})$, and the components are assumed independent. There have been many modifications to this general model idea (Van Leeuwen et al. 1996, Piepho and Ogutu 2002), allowing for different trends across streams. We used the functions written by Tom Kincaid to estimate power based on the model above; for specific details on the power calculations, refer to the paper by Urquhart et al (1998). These are *estimates* of the power because we are estimating the variance components. These estimates can be improved once more sampling is conducted within the specific KLMN parks.

We use a log transformation such that trend is in terms of a multiplicative change in the median O/E over time; this is typically appropriate for biological data that display exponential growth and increasing variability with an increase in mean. The residuals appeared to meet the model assumptions better on the log-scale for the PIBO data. The data used in the power analysis are displayed in Figure 6.

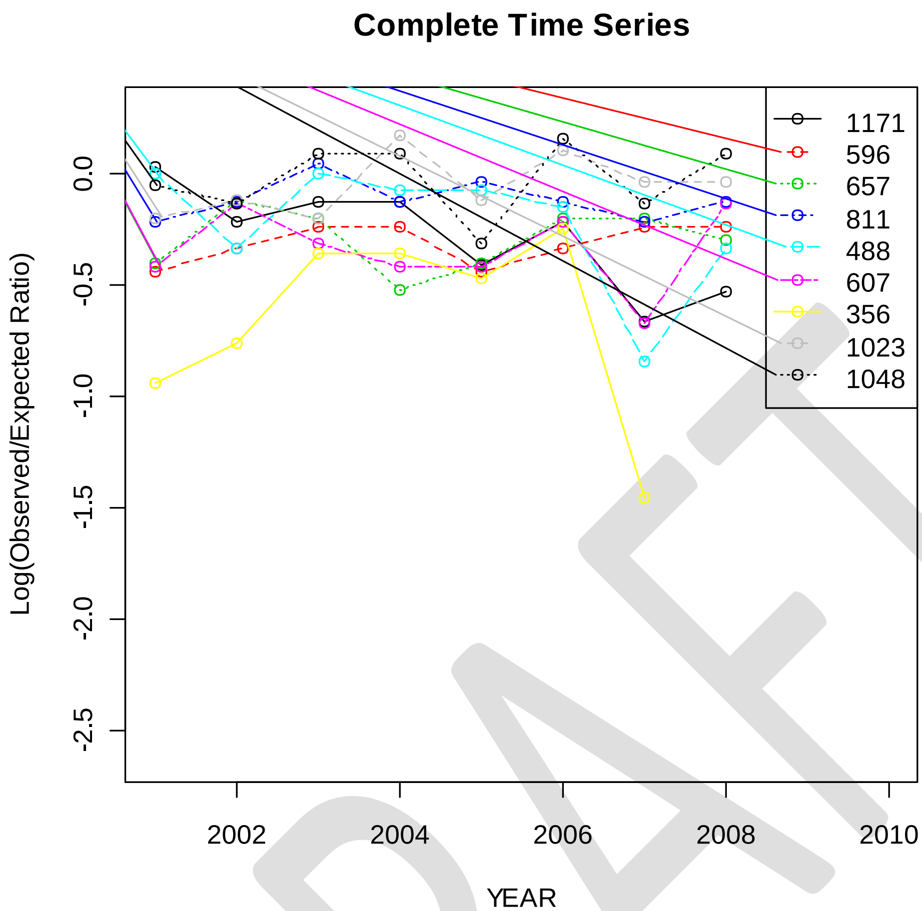

Figure 6. PIBO O/E ratios on the log-scale from nine sites sampled in 2001-2008. Numbers refer to PIBO site codes.

The Observed-to-Expected ratios for streams to be sampled within the Klamath Network should be consistent with those displayed in Figure 6. We maintain that the O/E ratios from the PIBO data represent a model of the site and annual variation because: (1) identical collection techniques were used, and (2) O/E models are built and calibrated regionally using identical methods, so that the performance characteristics should comparable.

The estimated power is based on the assumption that 15 streams are surveyed every 3 year period (always revisit design) and the available PIBO pilot data O/E represents the stream-to-stream, year-to-year, and stream by year variation within a Klamath Network sampling frame. For 10 sampling occasions or 30 years of elapsed monitoring, there is greater than 80% power to detect a 5% or 10% three-year change in log(O/E) ratio with 10% type 1 error (Figure 7). These 3-year changes correspond to 20% and 50% net change in the median O/E ratio after 30 years, respectively. For a smaller 3-year change of 2%, the power is substantially lower (as expected).

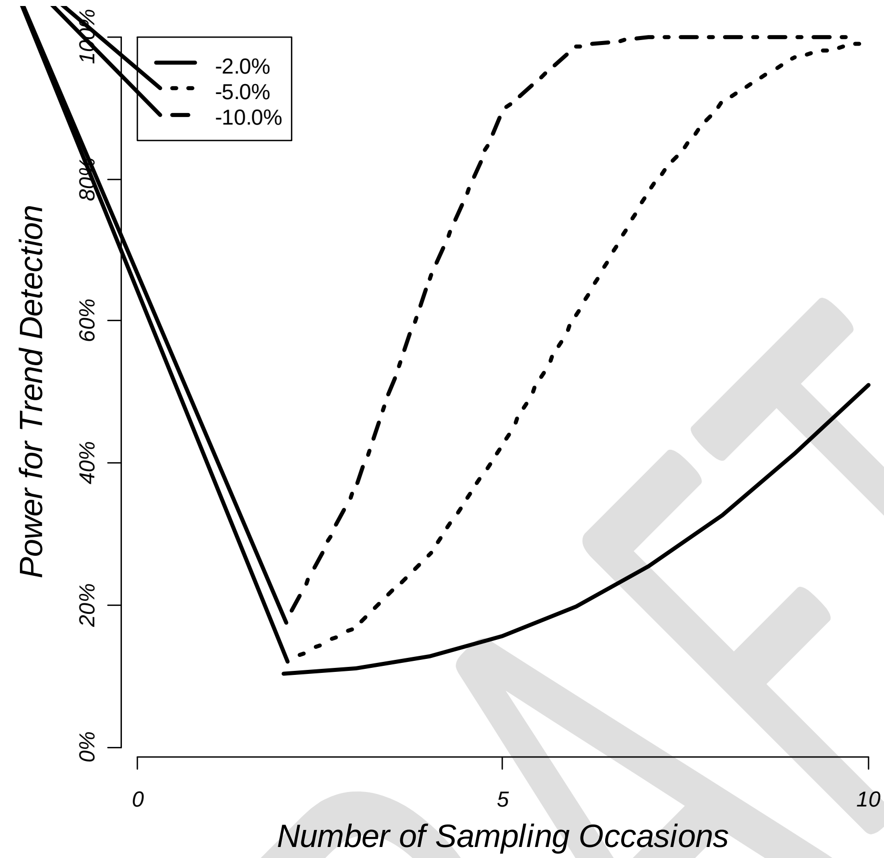

Figure 7. Power for O/E ratio using variance component estimates based on only the PIBO displayed in Figure X. Assuming 15 sites surveyed every 3 years with an every 3 year change of ¯2, ¯5, and ¯10 percent change in the median O/E (on log-scale)/

Additionally, many of our protocol objectives focus on a multivariate approach because we have chosen to analyze community change using species assemblages. Primary methods for the analysis of community data are non-parametric methods, for which there is no theoretical basis for power analyses (Somerfield et al. 2002). In other words, it is impossible with the current body of statistical literature to run power analyses on our primary method of data analysis. The utility of using univariate measures to assess a sampling program based on multivariate analyses is summarized by Somerfield et al. (2002):

> *"Multivariate techniques have been shown repeatedly to be more "sensitive" (i.e. powerful) than univariate techniques (Warwick and Clarke 1991, Somerfield and Clarke 1997, Clarke and Warwick 2001) and although there is no general framework for determining power in the multivariate context the repeated demonstration that multivariate technique produce significant results when univariate techniques do not may be taken as evidence that a survey designed to have adequate power in a univariate context (e.g. for diversity indices) should have adequate power in the multivariate context (of changes in whole community composition)."*

Second, many of our variables are measured to provide context for other parameters. For example, anions and cations are measured to understand stream chemistry in relation to the biological community but not as parameters for trend detection by themselves. So, although some parameters may have extremely low power due to high variability, this does not limit their usefulness for the monitoring program.

3.0 Field and Laboratory Methods

3.1 Data and Sample Collection

The attached Standard Operating Procedures (SOPs) describe field collection methods in detail, including pre-season preparation, water sampling and handling, physical habitat sampling, aquatic community sampling, shipping of samples, and end of season procedures (Table 3).

Table 4. Standard Operating Procedures covering the preparation, collection, and recording of field data for the integrated aquatic community and water quality sampling of streams.

SOP	Title and Description
SOP #1	**Preparations, Equipment, and Safety**
	A general overview of the steps necessary for the initiation of a field season. It covers tasks that the Project Lead will have to start early on in the planning process: hiring of field crews, equipment preparation, scheduling of crews, and basic safety is discussed.
SOP #2	**Field Crew Training**
	Covers the requirements for getting crews trained for the upcoming season, including field sampling procedures, ethical considerations, administrative processes, and data management training.
SOP #3	**Site Selection**
	Provided to give an overview of the site selection process and to inform the field crews of how the sites were initially selected, but this protocol will only have to be performed once at the initial implementation of the program.
SOP # 4	**Data Entry**
	Explains the use of tablet computers and data sheets used to record data collected during field procedures.
SOP #5	**Work Flow**
	Describes the most efficient method for performing the remaining SOPs to minimize time and so that any one sampling activity does not interfere with or contaminate another.
SOP #6	**Site Arrival Tasks and Sample Reach Layout**
	Describes the initial tasks the crew must achieve upon arrival to the reach and how to layout the transects that form the basis of the sampling.
SOP #7	**Water Quality Multiprobe Calibration and Field Measurement**
	Describes how to calibrate the water quality sonde prior to sampling, and the methodology of using the instrument to collect and record field data.
SOP #8	**Water Chemistry Sample Collection and Processing**
	Describes the methodology used for collecting water samples and how to process and store them.
SOP #9	**Macroinvertebrate Collection**
	Describes the process of collecting reach-wide benthic macroinvertebrates.
SOP #10	**Discharge Measurements**
	Describes the steps to calculate the instantaneous discharge at the time of sampling.
SOP #11	**Periphyton Sampling**
	Describes where and how to collect, process, and preserve the algal periphyton sample.

Table 3. Standard Operating Procedures covering the preparation, collection, and recording of field data for the integrated aquatic community and water quality sampling of streams (continued).

SOP	Title and Description
SOP #12	**Stream Habitat Characterization**
	Describes methodology of transect-based physical habitat characterization.
SOP #13	**Slope Measurements**
	Describes the process of measuring slope for the reach.
SOP #14	**Riparian, Invasive Plant, and Dominant Tree Characterization**
	Describes the monitoring methodology for basic riparian, invasive plant, and dominant tree measurements.
SOP #15	**Aquatic Vertebrate Monitoring**
	Describes techniques for electrofishing and visual encounter surveys.
SOP #16	**Photo Points and Photo Management**
	Describes the placement and method of photo points and photo management.
SOP #17	**Post-Site Tasks**
	Describes the necessary steps and tasks to be undertaken after sampling, and before sampling a new reach
SOP #18	**Post-Field Season**
	This SOP describes tasks to be undertaken by the field crew at the end of the season, including equipment clean-up, inventorying, storage, and post-season de-briefing.

3.1.1 Field Season Preparation

Standard Operating Procedure #1: Preparations, Equipment, and Safety details the necessary steps needed for ensuring a well organized field season. Tasks are briefly summed here, but SOP #1 provides greater depth and detail.

It is imperative that field season preparations starts by January of the sampling year. Preparation should start with field crew hiring. Ideally, positions will be announced in January, so it may be necessary to have Human Resources start the procedure as early as December of the previous year. Other preparations to be arranged prior to the field season include obtaining permits and scheduling park housing for field staff.

Field vehicles needs should be calculated in January. In coordination with the Network Program Assistant, the Project Lead should arrange for a vehicle through: (1) use of existing Network vehicles, (2) procurement of a new Government Service Administration (GSA) vehicle, or (3) a rental vehicle (arranged through GSA).

Purchasing and preparation of supplies should begin in February of the year in which sampling is to take place. Consumables (bottles, calibration solutions, etc.) should be inventoried and prepped according to procedures outlined in the SOPs. It is the responsibility of the Project Lead to check that all electronic equipment is functioning properly and all software is up to date.

Training should start with supplying the protocol to new hires upon completion of the hiring paperwork. The Project Lead should include scheduled classroom time for instruction in equipment use, followed by practical hands-on use at a field site, allowing ample time for instruction in all aspects of the protocol.

Permit requirements may change from year to year, depending on which parks are scheduled to be sampled and current requirements of park staff. Some parks require permits while some may allow research and collections by NPS employees without permits. Minimum Requirement Analyses (MRA) for sampling in wilderness areas may be required, especially at LAVO. Minimum Requirement Analysis is a method that park units use to ensure projects occurring in wilderness are justified and impart as minimal impact to the landscape as possible. The process to complete the MRA is administered as a follow-up to the park permitting process. The Project Lead will need to coordinate with the Chief of Natural Resources at scheduled parks well in advance of the beginning of the field season to ensure that all permits are secured.

Focal species covered by this protocol include fish and amphibians listed under the Endangered Species Act, for example: Crater Lake National Park contains bull trout (*Salvelinus confluentus*) and Redwood National and State Parks contains Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss irideus*). For anadromous fish, sampling (either in mortalities or handling [aka "take"]) is regulated by the National Oceanographic and Atmospheric Administration (NOAA) in their National Marine Fisheries Service (NMFS). For other threatened and endangered species, take is regulated by US Fish and Wildlife Service. It is the responsibility of the Project Lead to apply for permits well in advance of the sampling season (minimum 6 month lead time). Information for permits can be found at: http://www.nmfs.noaa.gov/pr/permits/.and http://www.fws.gov/Endangered/permits/index.html. Note that either agency may require the possession of state permits as well.

For California, the permit procedure is available at: http://www.dfg.ca.gov/licensing/pdffiles/fg1379.pdf

For Oregon, the permit procedure is combined with the NMFS procedure.

All reporting requirements for park, state, or federal permits are the responsibility of the Project Lead.

3.1.2 Field Work

Crews check-out field equipment and double check that all gear and field supplies are present in appropriate quantities and in proper functioning condition. Crews hike or drive to sampling reaches. Crews generally work from the downstream end to the upstream end of the stream reach to minimize effects of sampling disturbances on the accuracy of subsequent transects. For warmth and safety, crews wear chest high waders during sampling and should have spare clothes available. Crews will be carrying heavy loads into the backcountry; lightweight personal and sampling gear is encouraged. The sampling frame has placed an emphasis on streams that are accessible and can be sampled in a single day of travel. No overnight camping in wilderness should be necessary, but it will be encouraged if it facilitates sampling multiple sites efficiently.

Following the guidelines in SOP #5 (Order of Work), and for establishing the site (SOP #6: Site Arrival Task and Sample Reach Layout), crews collect water samples (SOPs #7 and 8), physical habitat data (SOPs #10, 12, 13, 14, 16), algal biomass samples (SOP #11), macroinvertebrates (SOP #9), and vertebrates (SOP #15). Invertebrate samples will be sent to an aquatic entomology laboratory but fish and amphibians will be processed and released in the field. At the discretion of the park, exotic fish may be euthanized and disposed in the field. Amphibians will be sampled using Visual Encounter Surveys. Amphibians will be handled only occasionally, as necessary to confirm species identifications.

Crews perform field alkalinity analyses using a portable test kit with minimal chemical requirements (mild sulfuric acid). All generated waste will be carried out by the crew and disposed of properly, meeting requirements of the Chemistry Department of Southern Oregon University.

3.1.3 Sample Handling and Shipping
Employees handling samples are required to adhere to quality control procedures to ensure sample integrity. All procedures detailed in the SOPs must be performed (SOP #17: Post-site Tasks). No "short-cuts" by field crews will be allowed. Water samples must be placed in a designated freezer or refrigerator as soon as possible by field crews upon return from the field. It is the responsibility of the Project Lead to secure access to such facilities for field crews. Water samples are shipped overnight to the lab from the Southern Oregon University mail room, using the Klamath Network administrative task agreement to cover charges. Samples should be shipped early in the week, to avoid the potential for samples to show up at the end-of-week workday, at a time when no one is available to receive them.

Macroinvertebrate samples are stored in 95% Ethanol to ensure adequate preservation. It is the responsibility of field crews to ensure that enough room in the sample vials exists to achieve this. All macroinvertebrate samples are retained by the Project Lead or field crews until the end of the season, when they will be shipped to an aquatic entomology laboratory. It is the Project Lead's responsibility to ensure that samples are properly tracked (SOP #19: Quality Assurance Project Plan) and shipped legally (it is illegal to ship Ethanol and other flammable liquids without special certification and training). The Project Lead should work with the aquatic entomology laboratory to meet these requirements. One possible solution to shipping Ethanol is the temporary replacement of Ethanol with water and overnight shipping. The aquatic entomology laboratory can than replace the water with Ethanol, so that minimal degradation to the samples has been incurred.

3.1.4 End of Season Procedures
Once sampling is complete at all sites, gear is decontaminated a final time, cleaned, repaired as needed, and stored. Crews will make a list of gear needing to be replaced or repaired and it is the Project Lead's responsibility to make certain the gear is ready for the following field season following the procedure in SOP #18: Post-season Tasks.

The Project Lead will conduct a post-season debriefing with field crews to discuss the season and make sure that all necessary protocol-related processes have been done. Any departures from the protocol will be discussed and analyzed. Necessary revisions and improvements to protocols will be discussed and if necessary, done in accordance to SOP #24: Revising the Protocol. Prior to the Crew Leader leaving, the Project Lead needs to review all data components with him/her to make certain final copies of all data related to the project are stored in their proper location on the KLMN Server, data on electronic equipment have been removed, and data-related questions or issues have been resolved.

3.2 Field and Laboratory Analyses

Laboratory methodologies and instrumentation have been chosen that match national standards, that are identical to methods used at Crater Lake National Park, and that match the methods used by the North Coast and Cascades Network. With the exception of the measurements that will be made in the field (acid neutralizing capacity, temperature, dissolved oxygen, pH, conductivity, and turbidity [Table 4]), all chemical analyses will be performed by contract laboratories (Table 5).

Field analyses and methodological details are presented in Table 4. Seven cross transect measurements are made to ensure that water chemistry sampling is in a well mixed location using the *Manta* multi-parameter sonde and *Amphibian* data recording unit (Eureka Environmental). In keeping with the nature of a long-term monitoring program, the probe used may change as equipment wears out, technological improvements are made, and companies go in and out of business. Any change of equipment will follow the SOP #19: Quality Assurance Project Plan guidelines for cumulative bias, to ensure continuity of reliable data and documented using equipment log books.

Table 5. In situ measurements, methods, and quality standards for water quality measurements. Specifications from Eureka Environmental, **www.eurekaenvironmental.com**. NTU = Nephelometric Turbidity Units.

Measurement	Method	Range	Accuracy	Resolution
Depth	Pressure transducer	0 - 25 m	± 0.2%	0.01 m
Dissolved oxygen	Optical luminescence	0 - 25 mg/L	± 1% or 0.2 mg/L, whichever is higher	0.01 mg/L
pH	Reference electrode	2 - 12 units	± 0.2 units	0.01 units
Redox potential	Reference electrode	-999 - 999 mV	± 20 mV	1 mV
Specific Conductance	4-Electrode Graphite Conductivity Sensor	0 - 5 mS/cm	± 1%	0.001 mS/cm
Temperature	30k ohm thermistor	- 5° C - 50° C	± 0.1° C	0.01° C
Turbidity	McVan NEP9500 type	0 - 3000 NTU	<1% when under 400 NTU	0.1 NTU

The sole field chemical analysis will be the determination of stream acid neutralizing capacity. Acid neutralizing capacity measurements will be accomplished using a Hach Digital Titrator Model 16900, following Hach procedure 8203. The range of this test kit is 10 – 4000 mg/L as $CaCO_3$; accuracy of the Digital Titrator is ± 1% for samples within the range of the test; resolution is one digit (1 mg/L for most circumstances), titrating to a pH endpoint of 4.8.

Klamath Network and Network park units do not have facilities, equipment, or personnel to conduct other laboratory analyses in-house, necessitating the contracting to a specialized laboratory. In general, the procedures will follow those recommended by the American Public Health Association (Eaton et al. 2005) and approved by the US Environmental Protection

Agency for water chemistry samples and by recognized standards for macroinvertebrate processing (Caton 1991, Vinson and Hawkins 1996). Macroinvertebrate laboratories must also use only taxonomists certified by the North American Benthological Society.
Ideally, contract laboratories will be reused from year to year to reduce laboratory bias. When change in laboratories is necessary, the cumulative bias procedure outlined in SOP #19: Quality Assurance Project Plan must be followed. Minimum internal laboratory Quality Assurance/Quality Control guidelines for contractor labs are provided in SOP #19: Quality Assurance Project Plan.

Table 6. Laboratory analyses to be conducted by a contract laboratory; minimum MDL, ML, and precision requirements. [1]= example instrumentation used by contract laboratory (Oregon State University CCAL) for pilot project. APHA = American Public Health Association (Eaton et al. 2005); MDL = Method Detection Limit; ML = Minimum level of quantification.

Parameter	Method	Instrumentation[1]	MDL (mg/L)	ML (mg/L)	Precision (± mg/L)
Calcium	APHA 3111 D	Varian SpectrAA220	0.06	0.19	0.06
Chloride	APHA 4110 B	Dionex 1500 Ion Chromatograph	0.01	0.03	0.01
Dissolved Organic Carbon	APHA 5310 B	Shimadzu TOC-VCSH Combustion Analyzer	0.05	0.16	0.05
Magnesium	APHA 3111 B	Varian SpectrAA220	0.02	0.06	0.02
Nitrate	APHA 4500-NO3 F	Technicon Auto-Analyzer II	0.001	0.003	0.001
Potassium	APHA 3111 B	Varian SpectrAA220	0.03	0.1	0.03
Sodium	APHA 3111 B	Varian SpectrAA220	0.01	0.03	0.01
Sulfate	APHA 4110 B	Dionex1500 Ion Chromatograph	0.02	0.06	0.02
Total Nitrogen	APHA 4500-NO3 F; APHA 4500-P J. Persulfate digestion	Total Technicon Auto-Analyzer II	0.01	0.032	0.01
Total Phosphorous	APHA 4500-P B; APHA 4500-P E	Milton-Roy 601 Spectrophotometer with 10 cm pathlength	0.002	0.003	0.002

4.0 Data Management, Analysis, and Reporting

The clear, concise, and consistent collection, recording, analysis, archiving, and reporting of data is essential to the success of the long-term monitoring of Klamath Network wadeable streams project and will be a top priority for all personnel. Data management is an ongoing cycle for each year the project is implemented and includes training, data collection and entry, validation and verification processes, documentation, distribution of project products, storage, and archiving (Mohren 2007). These steps are described in detail in the SOPs referenced below.

4.1 Quality Assurance Project Plan

A key component of data management is Quality Assurance/Quality Control. Quality Assurance is methodical, systematic planning of a program to ensure that products produced meet specified standard requirements (Irwin 2008). These steps include elements of sample design, parameter selection, reporting, and a feedback loop to improve quality. Quality Assurance also includes the important steps of Data Management: (1) Validation, (2) Verification, and (3) Certification (see below). Quality Control is the documentation of the standard requirements to be met under the program, and include quantitative performance characteristics like precision, bias, and sensitivity for all parameters measured. These steps are integrated into a single document, SOP #19: Quality Assurance Project Plan (QAPP). This SOP lists the steps and processes needed to ensure that data produced in the project is of a known quality.

4.2 Database Design

The water quality component of the Natural Resource Challenge (NRC) requires that all NPS networks archive any physical, chemical, and biological water quality data collected with NRC water quality funds in the NPS STORET (STOrage and RETrieval) databases. To assist in this process, networks have the opportunity to make use of a relational database patterned after the Natural Resource Database Template (NRDT) and developed by the Water Resources Division (WRD) called NPSTORET, or they can utilize any of the numerous databases already available as long as they can export that data into a format that meets the STORET Electronic Data Deliverable (NPSEDD) specifications. We have opted to develop a NRDT compliant, network-specific database that meets the NPSEDD specification for all aquatic and water quality monitoring projects. It was determined that NPSTORET did not have all the functionality needed to account for all the data being collected as part of this integrated protocol. The relational database was developed using the NPS Natural Resource Database Template (NRDT) and is described in detail in SOP #20: Database.

Crews use the project database to enter data into Tablet PCs (SOP #4: Data Entry) at each monitoring site, with paper field forms as a backup. After QAPP procedures (including validation, verification, and certification) are completed, this database is used to create summaries and conduct data analysis for annual reports. At the end of the year, the data are uploaded to a master database for long-term storage and future analyses.

4.2.1 Metadata Procedures

Creation of metadata is an integral part of any project that collects samples that generate data and information. Metadata consists of information that documents the information contained within data files and information products. In other words, metadata is “data about data.” The overall goals of metadata creation are to develop a comprehensive document that explains enough about the project data to ensure they are useable by future personnel and the scientific community (providing important future context). Metadata development begins at the start of every project; as the project develops, so does the metadata. Within the sideboards set by the program and federal requirements, the process of metadata creation will vary depending on goals and objectives, funding, and scope of the project. It is the responsibility of the Data Manager to set forth the metadata requirements and the process used to create the metadata.

Database, Spreadsheets, and Data Sheets: The metadata for a project should be created prior to implementing the field season and will need to be updated at the end of each field season. The Klamath Network utilizes a Metadata Interview form that describes the various attributes of a dataset. The interview form includes information about the time frame, description, sensitivity, collection location, and purpose of the data, plus various other pieces of information needed to develop the metadata for the dataset. It is the Project Lead's responsibility to complete a new Metadata Interview form before the start of the first field season and at the end of each additional field season. In addition to the Metadata Interview form, a data dictionary is provided for all databases and spreadsheets used as part of this protocol (SOP #20: Database). During the winter months, prior to starting the field work, the Project Lead will review the data dictionary and work with the Data Manager to make any necessary changes.

GIS & GPS Files: Similar to the data products above, the KLMN will utilize the Metadata Interview form to manage the metadata for these products. The metadata for all GIS files created as part of this protocol will consist of Federal Geographic Data Committee compliant metadata before being made available to non-Network staff.

Photographs: The Klamath Network requires metadata to be provided for each photograph used to capture some aspect of a monitoring project (e.g., field crew, sites, sampling method). These details are provided in SOP #16: Photo Points and Photo Management.

Documents: We expect to develop several types of reports as part of this protocol including publications, technical reports, outreach materials, resource briefs, and in-house reports. All reports should contain the following information when applicable: first and last name of the author(s), affiliation, version number (when in draft form), date the report was completed, series number, and the NatureBib accession number (in the document properties).

4.1.2 Storage

When collecting data electronically in the field, a backup of the database will be made prior to leaving a field site. The backup of the database should be stored to a source that is external of the electronic device. Once back to the field base (e.g., park housing), data from the electronic devices should be stored in a desktop or laptop computer. These steps are detailed in SOP #17: Post-site Tasks.

When returning to the Klamath Network office, data should be reviewed by the Project Lead. Once the data have undergone all validation and verification processes, they should be transferred to the Network Data Manager. Data will follow the backup process implemented by Southern Oregon University that includes nightly, weekly, and quarterly backups stored for 2 months (nightly and weekly backups) or 1 year (quarterly backups) (SOP #23: Data Transfer, Storage, and Archive).

4.2 Data Collection

Steps and procedures used for data collection is the primary purpose of SOP #s 4 through 17. It is the responsibility of the Field Crew Leader and Project Lead to adequately train field crews in data collection and management methodologies outlined in this protocol (SOP #2: Field Crew Training). Since this protocol is a long-term commitment and crew turnover is expected, a training session on the database, based on the Data Entry SOP (#4), is necessary each season. A log should be kept outlining the training sessions each crew member attends and logs should be transferred to the Data Manager at the end of each field season.

All data collection and data management tasks related to the entry of data are detailed in SOP #4: Data Entry, which includes the use of backup paper data sheets in case of electronic equipment failure. Data sheets and logs (documenting training, equipment calibration, and other events) are scanned into .pdf format for electronic archival at the end of the season following methods outlined in SOP #23: Data Transfer, Storage, and Archive.

4.3 Data Verification, Validation, and Certification

Data verification is the process of ensuring that data entered into a database accurately duplicate data recorded in the field. Field crew members and the Project Lead use the following process to verify data and are described in detail in SOP#19: Quality Assurance Project Plan: (1) Visual review at data entry, (2) Visual review after data entry, and (3) Final review.

Data validation is the process of reviewing the finalized data to make sure the information presented is logical and accurate. The accuracy of the validation process can vary greatly and is dependent on the reviewer's knowledge, time, and attention to detail. General data validation procedures are detailed in SOP #19: Quality Assurance Project Plan and include: (1) Data entry application programming, (2) Outlier detection and review, and (3) Review of what makes sense.

After data validation and verification, the Project Lead will turn in a Data Certification form(s) (from the Klamath Network Data Management Plan, Mohren 2007) to the Data Manager. This form is used to ensure:

- The data are complete for the period of time indicated on the form.
- The data have undergone the quality assurance checks indicated in the protocol.
- Metadata for all data has been provided.
- Project timelines are being followed and all products from the field season have been submitted.
- The level of sensitivity associated with the deliverable is appropriate.

A new Certification form should be submitted each time a product is submitted. If multiple products are submitted at the same time, only one form is necessary. The form and further instructions for data certification are provided in SOP #19: Quality Assurance Project Plan.

4.4 Data Analysis, Reporting, and Dissemination

Data analysis, reporting, and dissemination guidelines are covered in SOP #22: Data Analysis and Reporting. This SOP covers a comprehensive approach by the Klamath Network of the reporting of data for the next 12 years. There will be two elements of our reporting strategy: (1) Annual Reports describing field sites visited, interesting findings, and status of the measured parameters completed every sampling period and (2) Analysis and Synthesis reports completed every 3 years that focus on trends and comprehensive descriptions of the attributes of the stream ecosystems. Reporting topics, timelines, and dissemination are covered in more detail in SOP #22: Data Analysis and Reporting.

4.4.1 Annual Reports

Annual reports are summaries of the wadeable streams sampled for a field season. An example of an annual report is provided in Appendix A, from the data collected during the pilot project. These reports will focus on providing managers a current status assessment, defined using measures of central tendency (means or medians) of the park habitats. Since wadeable streams have a large history of bioassessment tools (e.g., Indices of Biotic Integrity), annual reports will include these summary values assessing ecosystem condition. Reporting tools will focus on mean conditions, along with user-friendly graphical presentations. Unusual or significant findings will also be highlighted. Annual reports serve to update the park units where sampling occurred for their use in management and reporting goals.

Due to necessary turn-around times for contract laboratories, summary reports will be due June 1st of the year following stream sampling. This will provide approximately 180 days for the contract laboratories to process invertebrate samples and an additional 3 months for the Project Lead to complete the report. Report format will be the Natural Resources Technical Report (NRTR) series format.

4.4.2 Analysis and Synthesis Reports

Analysis and Synthesis reports form the basis of trend analysis for the integrated aquatic communities and water quality vital signs. In the spirit of long-term sampling, the protocol will run through several sampling periods before meaningful analyses can be completed. The first Analysis and Synthesis report will occur after the second sampling period, 2 years after implementation, and include all parks sampled as a part of this protocol. As in the Annual Reports, they will occur every 3 years thereafter. Reporting format will follow the NRTR format.

The initial Analysis and Synthesis reports will focus on describing the fundamental aspects and gradients of the streams: (1) Physical, (2) In-stream communities, and (3) Riparian Interactions. An individual report will be devoted to each aspect of the stream, starting with the least variable: the physical environment. The second will focus on the in-stream communities (invertebrates, amphibians, and fish) of the stream ecosystems. The third Analysis and Synthesis report will examine how riparian measures interact with the physical and biological aspects of the stream communities. This report will, where applicable, integrate data from other vital signs that are sampled near the stream reaches (Landbirds, Vegetation Communities, and Land Cover).

The fourth Analysis and Synthesis report will be the first major analysis of trends. This will be after four sampling periods and will be due on the 1st of November, 2022. Although this lag between implementation and the first trend analysis seems unduly long (11 years), this is close to the minimum number of sampling periods needed to achieve significant trends with the Mann-Kendall test at the α level of 0.05 level (Rohlf and Sokal 1995); trend analyses prior to this would be of limited usefulness. This report will be a comprehensive study on the techniques to detect trends and will outline the methods to be used in future trend analyses, recognizing that the field of ecological statistics and trend analysis will always be an innovative and evolving one.

The Project Lead is encouraged to explore other aspects of monitoring and research as well. Possible topics include: (1) Bayesian statistics applications; (2) Status and trends in a regional context (i.e., integrating data from other regional programs); and (3) Reanalysis of sampling frame (e.g., have streams become inaccessible, park land base increased, or have perennial habitats become ephemeral). In determining the topics to be covered by Analysis and Synthesis reports, park staff at the respective park units should be consulted to explore specific management or research needs that may be answerable using the data from this protocol.

4.4.3 Data Dissemination
It will be the Project Lead and the Klamath Network Data Manager's responsibility to utilize the season's certified raw data along with the materials presented in the Annual report, Analysis report, and Metadata Interview form to populate or update the NPS Inventory and Monitoring databases including NPSpecies and the NPS Reference Application. In general:

- All reports will be posted to the reference application and KLMN Internet and Intranet web pages.
- The full report will be sent to the Resource Chiefs of each park and to any park staff that are associated with the project.
- A short, one-page summary of the report will be sent to all park staff.
- Reports will be linked to the corresponding species in NPSpecies.
- Photographs and metadata provided for photographs will be stored in the project folder located on the Klamath Network shared drive, where only the Data Manager will have write access but all KLMN employees will have read access.
- After all QA/QC procedures have been completed (including validation, verification, and certification) of all data products (field and lab), the data are sent annually to the Water Resources Division for inclusion in WRD STORET. Water Resources Division then uploads the data, once they have done any edits or QA/QC procedures, to the EPA STORET National Data Warehouse (www.epa.gov/storet/dw_home.html).
- Once Annual reports, raw data, and GIS files have been reviewed and finalized, they will be packaged together along with their associated metadata and posted to the reference application system after the holding period listed below.

4.4.4 Holding Period
To permit sufficient time for priority in publications, when data are sent to the park staff or the public, it will be with the understanding that these data are not to be used for publication without contacting the Network Contact. The raw data is sent to WRD and reference application one year after collection for general distribution. Note that this hold only applies to raw data and not to metadata, reports, or other products that are posted to NPS clearinghouses immediately after being received and processed.

4.4.5 Sensitive Information
Certain project information related to the specific locations of rare or threatened taxa may meet criteria for protection and as such should not be shared outside NPS, except where a written confidentiality agreement is in place prior to sharing. Before preparing data in any format for sharing outside NPS, including presentations, reports, and publications, the Project Lead should refer to the guidance in SOP #21: Sensitive Data. Certain information that may convey specific

locations of sensitive resources may need to be screened or redacted from public versions of products prior to release. All official FOIA requests will be handled according to NPS policy. The Project Lead will work with the Data Manager and the FOIA representative(s) of the park(s) for which the request applies.

5.0 Personnel Requirements, Training, and Safety

5.1 Roles and Responsibilities

The Integrated Aquatic Community and Water Quality Monitoring of Wadeable Streams in the Klamath Network program is the responsibility of the Network Aquatic Ecologist, also referred to as the Project Lead. The Project Lead is a GS-9/11/12 level scientist who is trained and experienced in aquatic ecology, with hands-on experience in lentic and lotic habitat ecology, either through postgraduate education or work experience. The Project Lead is responsible for managing the day-to-day activities of the streams project; supervises seasonal crew members and provides them with tactical and logistical support during the field season; verifies, validates, and analyzes data; and writes and completes Annual and Analysis and Synthesis reports.

Assisting the Project Lead is the Network Coordinator, who has overall responsibility for implementing and supervising this project; is responsible for the successful completion of all aspects of the project; and directly supervises the Project Lead and Data Manager. The Data Manager is responsible for creating and maintaining the seasonal and master database; providing data management guidance and training to project staff; and ensuring the data are accurate, properly documented, stored, archived in a secure manner, and made available to a diverse audience.

The field crew will consist of four members: a senior Field Crew Leader and three junior Field Crew Members. With the number of reaches to be visited in this protocol at 60 or 61 (depending on the parks to be sampled), a single crew can sufficiently sample all reaches during the field season.

The Field Crew Leader is supervised by the Project Lead, is accountable for supervising crew members and any volunteers in the field, and is responsible for the successful completion of the field component of this protocol. This includes but is not limited to the collection, storage, and shipment of field samples and the collection and entry of data into the monitoring program database. The Field Crew Leader is responsible for the calibration, use, and/or maintenance of monitoring program equipment. He or she is also responsible for providing recommendations on how to improve the task outlined in the protocol. The Field Crew Leader needs experience in conducting aquatic field work in relatively remote locations, at least some experience in supervising peers, and the ability to live and work cooperatively with others under often stressful and challenging conditions for extended periods.

The field crew members are supervised by the Field Crew Leader and will be responsible for successfully completing all monitoring program tasks, including but not limited to the collection, storage, and shipment of field samples and collection, verification, and entry of field data. The field crew members will have at a minimum some experience in conducting aquatic field work in relatively remote locations and have demonstrated ability to live and work cooperatively with others under often stressful and challenging conditions for extended periods.

5.2 Training Procedures

A standardized, comprehensive training program for all personnel is necessary to ensure that data collection is consistent and meets the data quality objectives listed in various SOPs in this protocol and the data standards defined in the Klamath Network Data Management Plan. The training program should last 2 weeks, although actual data collection under Project Lead supervision can and should be conducted during this period.

The training program should start with classroom sessions, with the Project Lead, working closely with the Data Manager, GIS Specialist, and Program Assistant, developing instructional materials that cover the following topics (the list can be expanded):

1. Background on I&M program objectives.
2. Administrative tasks (timesheets, vehicle procedures, reimbursement, etc.).
3. Sampling design, and data analysis.
4. Field sampling methods and QA/QC concerns.
5. Equipment operations and maintenance.
6. Field and laboratory sample processing and handling.
7. Fish and amphibian species identification, handling, and a primer on wildlife diseases.
8. Recording and storing data, both manually and digitally.
9. Safety in the backcountry.
10. Orienteering.
11. Backcountry rules and ethics.
12. Computer data entry.

This educational period is supplemented with this narrative, protocol, and appendices, but these materials (to be supplied before the Entrance on Date [SOP #1: Preparations, Equipment, and Safety]) are not to be used as a substitute for a training period.

Classroom training material will be developed by the Project Lead and stored in electronic form on the Klamath Network server, following protocols in the Data Management Plan. Over the course of this protocol implementation, these materials will be refined and improved by the Project Lead.

After the classroom sessions, additional training focuses on hands-on collection of data in the field. This can take place at an established reach within the appropriate park unit and be used as actual data for the program, with the Project Lead on hand to supervise and train the crew in proper techniques. For example, the Project Lead can take a water quality sample as a demonstration, which will be actual sample of “record,” but can be repeated by the field crew members to learn the sampling techniques. Each crew member will be certified in each SOP, with date certified, individual responsible for certification, and specific SOP certified recorded using the forms provided in Appendix F.

5.3 Safety

Safety of the field crews is a top priority of this project. The program architecture included this consideration in the sampling frame, ensuring that site areas are accessible and can be sampled within a single day, minimizing the need for travel outside of daylight hours. Likewise, we will only sample streams with a less than 15% slope, so that crews are not working on steep streams. Additionally, field crews are provided with a copy of the USGS Safety Manual (Appendix C) and Job Hazard Analyses (Appendix N).

6.0 Operational Requirements

6.1 Annual Workload and Field Schedule

Necessary tasks for the implementation of this protocol are presented in Table 6. Preparation for the upcoming field season starts the year before, ideally in December or earlier. By January, the Project Lead should re-inventory and recheck the condition of the field gear and order replacements or send them to the manufacturer for servicing as necessary. (Checks will be done at the close of the last season, but with 2 years between sampling, gear must be rechecked.) In April, the Project Lead should obtain bids for specimen processing (water chemistry, Chlorophyll *a*, and macroinvertebrates) and initiate contracting to the chosen laboratory. Water chemistry bottles should be acid washed (or confirm that pre-acid washed bottles are ready in suitable numbers) and filters prepared for water sample collection (SOP #1: Preparations, Equipment, and Safety) in April, with all associated tasks completed by the middle of June. Training of the field crew should begin in July, at the start of the field season. Training is an on-going activity; periodic checks will be made to ensure that QA/QC procedures are followed. Although data entry will occur throughout the field season, a final QA/QC will occur with the presence of the field crew, so that any remaining questions may be answered. Upon data certification and receipt of the data deliverables of the specimen contractors, the Project Lead will formulate and write the Annual report and/or Analysis and Synthesis report, as appropriate. The first stages of this could occur in October. However, initiation of the report writing may be delayed relative to the availability and delivery of the required data. Report(s) should be finalized by June of the following year.

Table 7. Summary of annual tasks and workload for implementation of protocol. N/A indicates not applicable, either an ongoing task, or open ended.

Task	Timeframe to initiate	Deadline
Hiring of Field Crew	December - January	End of January
Inventory and maintain field gear	January - February	End of February
Purchase required field gear	March	March
Acquire bids for specimen processing, arrange contracting	April	End of May
Prepare water chemistry bottles and filters	April	Middle of June
Training and orientation	July	N/A - Ongoing
Field work	July - October	N/A
Final Data Entry and QA/QC	October	September
Annual Report and Analysis and Synthesis Reports	November	June of following year

6.2 Facility and Equipment Needs

Facilities necessary for the completion of this protocol include office space with access to computers for the Project Lead, as well as computers for data input from the seasonal field crew. Minimal laboratory facilities are necessary for the steps of acid washing bottles and filter prep and are all available through Southern Oregon University Chemistry Department. Seasonal housing for the field crews is also necessary, along with access to refrigeration/freezer usage for storing water samples.

A large amount of equipment is necessary for the completion of this protocol. A complete equipment list is provided in Appendix M, along with quantity needed per site and per sampling season. The large amount of bulky equipment, along with a four-person crew, necessitates a large vehicle for transport.

6.3 Budget Considerations

Total annual operating budget of the protocol is budgeted for $110,000. This budgetary figure does not include the costs of the core Network staff (see below). The annual cost is split between WRD budgetary funds and Klamath Network funding. The first year of the implementation budget has been developed to be under this amount so that inflationary cost increases over the long-term will not jeopardize program viability. Our goal has been to ensure that the program stays financially sound for a minimum of 7 years, under an assumption of no programmatic budget increases. We have assumed a typical inflationary increase in all costs (salary, benefits, sample processing, and equipment) of 3% per year. Hence, to come just under the budget of $110,000, our budget for 2011 (the first year of implementation) is $91,484.40 (Table 7).

Additional budget considerations and costs come from the core Network staff, consisting of:

- Project Lead (assuming GS-11 level): approximately 20 pay periods at $2,600 per = $52,000 (the Project Lead time in a streams year will also include preparation work for stream or lake monitoring in upcoming year).
- Network Coordinator (assuming GS-12 level): approximately 1 pay period at $3,200 per = $3,200.
- Network Administrative Assistant (assuming GS-07 level): approximately 1.5 pay periods at $1,406 per = $2,107.
- Network Data Manager (assuming GS-11 level): approximately 1.5 pay periods at $2,600 per = $3,900.
- Total costs of core Network staff = $61,207.

Table 8. Budget for implementation of the Integrated Aquatic Community and Water Quality Wadeable Streams in the Klamath Network Protocol. Numbers in parentheses and red indicate a programmatic deficit, assuming no budgetary increases**.**

Program Item (@2010 costs)		2011	2012	2014	2015	2017	2018
Salary							
	GS-7 Field Crew Leader 1FTE @10PP; $1460.80 per PP	$14,608.00	$15,046.24	$15,962.56	$16,441.43	$17,442.72	$17,966.00
	GS-5 Crew Members 3FTE @9PP; $1179.20 per PP	$31,838.40	$32,793.55	$34,790.68	$35,834.40	$38,016.71	$39,157.22
Vehicle							
	Field transport/fuel	$3,000.00	$3,090.00	$3,278.18	$3,376.53	$3,582.16	$3,689.62
Travel							
	Lodging and per diem	$4,000.00	$4,120.00	$4,370.91	$4,502.04	$4,776.21	$4,919.50
Equipment							
	Consumables, field computers, replacement parts, etc.	$5,000.00	$5,150.00	$5,463.64	$5,627.54	$5,970.26	$6,149.37
Specimen Processing							
	Macroinvertebrates; 61 @ $250	$15,750.00	$16,222.50	$17,210.45	$17,726.76	$18,806.32	$19,370.51
	Water Chemistry; 61 @ $160	$10,080.00	$10,382.40	$11,014.69	$11,345.13	$12,036.05	$12,397.13
	Chlorophyll a; 61 @ $35	$2,205.00	$2,271.15	$2,409.46	$2,481.75	$2,632.89	$2,711.87
QAPP							
	10% extra samples; verification; probe and electroshocker maintainence, etc.	$5,000.00	$5,150.00	$5,463.64	$5,627.54	$5,970.26	$6,149.37
	Total	$91,481.40	$94,225.84	$99,964.20	$102,963.12	$109,233.58	$112,510.58
	Surplus/Deficit	$18,518.60	$15,774.16	$10,035.80	$7,036.88	$766.42	$(2,510.58)

7.0 Literature Cited

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